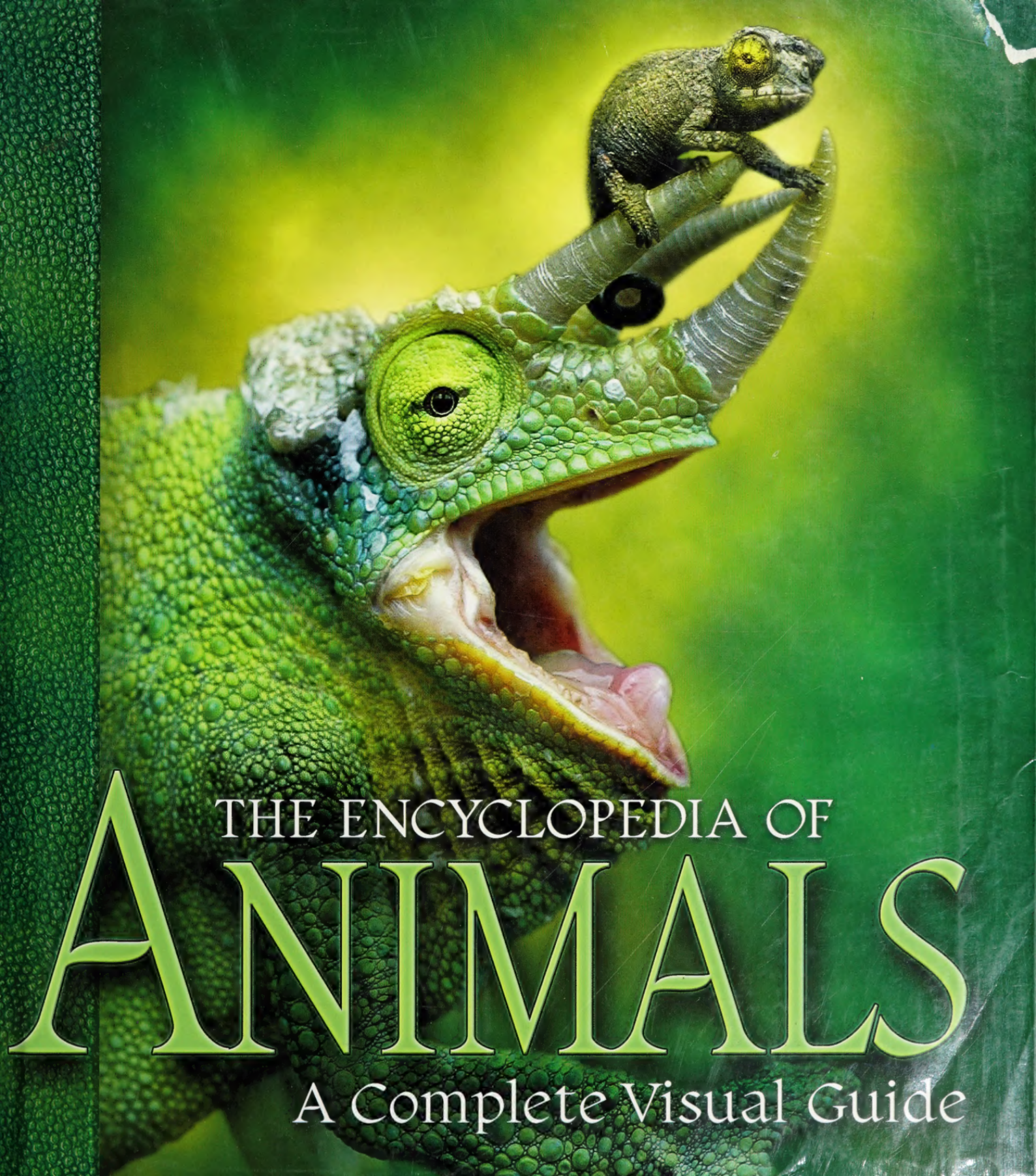

# THE ENCYCLOPEDIA OF ANIMALS

## A Complete Visual Guide

# THE ENCYCLOPEDIA OF ANIMALS

## A Complete Visual Guide

The variety of animal species is staggering. So, too, is the diversity of form, behavior, and adaptation that animals display. Even in seemingly inhospitable areas, such as arid deserts and frozen polar regions, animals have evolved characteristics that enable them to survive and thrive.

This lavishly illustrated visual reference book is an authoritative survey of the intriguing world of animals. The first section is an overview of animal evolution, classification, biology, behavior, habitats, and adaptations. Special attention is paid to current conservation issues.

At the core of the book is an encyclopedic survey of all the animal groups—mammals, birds, reptiles, amphibians, fishes, and invertebrates. A gallery of more than 2,000 species illustrations conveys the variety and wonder of the animal kingdom. These are supported by hundreds of detailed explanatory diagrams, distribution maps, and color photographs. Vulnerable and endangered species are clearly marked, and many are discussed in detail. Feature panels and pages focus on unusual or intriguing aspects of animal behavior. The text is completely up-to-the-minute, with the latest scientific findings and the most recent classification and conservation information.

With its rich visual content, stunning graphics, and informative text, *The Encyclopedia of Animals* is the ideal reference guide to the animal kingdom.

THE ENCYCLOPEDIA OF

# ANIMALS

A Complete Visual Guide

# THE ENCYCLOPEDIA OF ANIMALS

## A Complete Visual Guide

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University of California Press
Berkeley Los Angeles

CURRIC QL 7 .E54 2004

University of California Press
Berkeley and Los Angeles, California

Published by arrangement with
Weldon Owen Pty Ltd
59 Victoria Street, McMahons Point
Sydney NSW 2060, Australia
Copyright © 2004 Weldon Owen Inc.

**Chief Executive Officer** John Owen
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**Species Gallery Illustrations** MagicGroup s.r.o. (Czech Republic) — www.magicgroup.cz
Pavel Dvorský, Eva Göndörová, Petr Hloušek, Pavla Hochmanová, Jan Hošek, Jaromír a Libuše Knotkovi, Milada Kudrnová, Petr Liška, Jan Maget, Vlasta Matoušová, Jiří Moravec, Pavel Procházka, Petr Rob, Přemysl Vranovský, Lenka Vybíralová
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**Information Graphics** Andrew Davies Creative Communication

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Cataloguing-in-Publication data is on file with the Library of Congress

ISBN 978-0-520-24406-1

13 12 11 10 09 08 07 06
10 9 8 7 6 5 4 3 2

Color reproduction by Chroma Graphics (Overseas) Pte Ltd
Printed by Kyodo Printing Co. (S'pore) Pte Ltd
Printed in Singapore

A Weldon Owen Production

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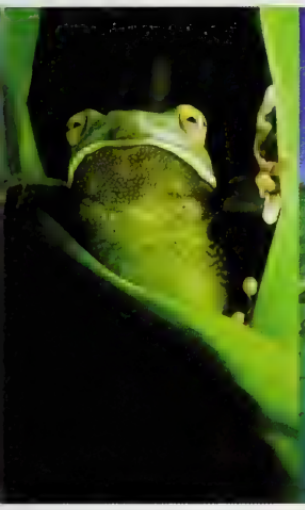

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# FOREWORD

Like any excellent natural history reference, *The Encyclopedia of Animals* will eventually be revised for two reasons, one of them admirable and the other profoundly sad. On the positive side, zoologists are still finding undescribed species, as well as discovering many new and surprising things about animals. Twenty-five years ago we knew of fewer than three thousand species of frogs and now the count stands at almost five thousand; only a decade ago parental care was regarded as exceedingly rare among snakes, but recently field biologists have determined that most female pitvipers attend their young for about a week after birth. Better ways to classify organisms are working their way into popular writing too, so we now correctly discuss crocodilians as more closely related to birds than they are to lizards—and thereby emphasize that nest building and vocal communication by alligators, eagles, and extinct dinosaurs likely reflect their shared heritage as archosaurs.

*The Encyclopedia of Animals* impressively conveys the real texture of biodiversity, that marvelously great variation among organisms themselves. Written by a team of experts, this book's coverage emphasizes mammals and birds, the two most popular groups of vertebrates, but it also treats other kinds of animals in timely detail. Here readers can push beyond familiar facts and trendy pandas to become acquainted with big-brained elephant fishes, gastric brooding frogs, the bizarre solenodon, and other improbable creatures; here they will meet an oft-slighted but fascinating group of amphibians, the limbless caecilians, and read about diverse, previously obscure invertebrates. Throughout the text beautiful artwork accurately depicts hundreds of species in life, while numerous outstanding photographs portray their special relationships with particular habitats.

The other, disturbing reason for one day updating this wonderful volume will be that the status of some species will change from threatened to extinct, and many others will become endangered. Environmental conservation is among our most important and formidable responsibilities, one that must start with education. The more we understand how richly diverse and how inspiringly adapted organisms are for their environments, the more we will care about them. Thus, to whatever extent humanity increasingly values animals in practical and esthetic terms, we will more readily make difficult personal and political choices in their favor. I hope that *The Encyclopedia of Animals* will encourage you to get out in nature, to appreciate animals all the more for what you have learned, and then to do what you can to conserve them.

**Harry W. Greene**
*Professor of Ecology and Evolutionary Biology at Cornell University*

# HOW TO USE THIS BOOK

The first section of this book provides an overview of animal life, animals through the ages, how animals are classified, their biology and behavior, habitats and adaptations, and animals in danger. Then follow six taxonomic sections, namely Mammals, Birds, Reptiles, Amphibians, Fishes, and Invertebrates. Each of the sections comprises an introductory feature discussing the group in general, then is broken down into chapters devoted to particular subgroups. The sections do not necessarily provide a similar amount of coverage; for example, there is a discrepancy between Mammals and Invertebrates, the latter profiling larger taxonomic groups to give sufficient coverage to Invertebrates as a whole. The book concludes with a comprehensive glossary and index.

**Group global distribution**
A map shows the worldwide distribution of the group being profiled, followed by text that discusses the distribution of particular groups in more detail

## HABITAT ICONS

The 19 habitat icons below indicate at a glance the various habitats in which a species or group can be found. It should be noted that the icons are used in the same order throughout the book, rather than in their order of significance. A more detailed profile of each habitat can be found on pages 40–53

- Tropical rain forest
- Tropical monsoon forest
- Temperate forest
- Coniferous forest
- Moorlands and heath
- Open habitat, including savanna, grassland, fields, pampas, and steppes
- Desert and semidesert
- Mountains and highlands
- Tundra
- Polar regions
- Seas and oceans
- [illegible]
- [illegible]
- Coastal areas, including beaches, [illegible] cliffs, sand dunes, intertidal rock pools, and/or coastal waters [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

**Section and chapter**
This indicates the group of animals under discussion.

**Classification box**
This indicates the taxonomic groups to which the animals belong in the animal kingdom.

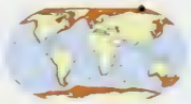
**Detailed diagram**
Where appropriate, diagrams are included to illustrate points about anatomy or adaptation

142 MAMMALS SEALS AND SEA LIONS

## SEALS AND SEA LIONS

CLASS Mammalia
ORDER Carnivora
FAMILIES 3
GENERA 21
SPECIES 36

With flexible, torpedo-shaped bodies, limbs modified to become flippers, and insulating layers of blubber and hair, seals, sea lions, and walruses are superbly adapted to a life in water. They have not, however, completely severed their link with land and must return to shore to breed. Collectively known as pinnipeds, these marine mammals were once placed in their own order, but are now considered to be part of Carnivora. Most feed on fish, squid, and crustaceans, but some also eat penguins and carrion and may attack the pups of other seal species. They can dive to great depths in search of prey, with the elephant seal able to stay submerged for up to 2 hours at a time



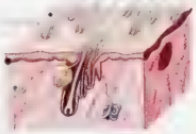
Cold-water creatures [illegible]

Communal living [illegible]

THREE GROUPS
There are three pinniped families. The Phocidae are known as the true seals. They swim mainly with [illegible] of their hind flippers, which cannot bend forward to act as feet, making their movement on land particularly [illegible]. Although their hearing, especially under water, is good, true seals lack external ears.

Sea lions and fur seals belong to the family Otariidae. These "eared [illegible]" have small external ears. They [illegible] mostly on their front flippers [illegible] swimming, and can bend the hind flippers forward when on land, allowing them to walk "four-footed" and sit in a semi-upright position.

The third family, Odobenidae, contains a single species, the walrus, instantly recognizable by the long canine teeth that form tusks in both sexes. Like true seals, walruses use their hind flippers for swimming [illegible] external ears. Like eared seals, however, walruses can bend their hind flippers forward.



Insulating layers [illegible]

**BRINGING UP BABY**
All pinnipeds return to land or ice to give birth and mate. Mating takes place just days after the usually single pup is born, but the fertilized egg does not become implanted in the uterus for months. This delayed implantation allows birthing, nursing, and mating to occur in one season so that the animals live on land, where they are most vulnerable, only once a year. Pups are dependent for varying lengths of time. Harp seals (right), for example, are nursed for only 12 days or so while walruses stay with their mother for 2 years

**CONSERVATION WATCH**
The commercial sealing operations that began in the 16th century had a devastating effect on pinniped populations. Of the 36 species of pinnipeds, 36% are listed on the IUCN Red List, as follows:

- 2 Extinct
- 1 Critically endangered
- 2 Endangered
- 7 Vulnerable
- 1 Near threatened

**Feature box**
This support text describes in detail a facet of the species' behavior or biology, and is accompanied by relevant photographs, illustrations, or diagrams

**Conservation watch box**
This provides information about the status of a particular species or group of animals, according to the IUCN Red List of Threatened Species. These boxes may also outline factors that threaten the animal's survival

## CONSERVATION INFORMATION

Within the fact files, each profiled species is allocated a conservation status, using IUCN and other conservation categories, as follows:

**+ Indicates that a species is listed under the following categories:**

**Extinct** (IUCN) It is beyond reasonable doubt that the last individual of a given species has died.

**Extinct in the wild** (IUCN) Only known to survive in captivity or as a naturalized population outside its former range.

**Indicates that a species is listed under the following categories:**

**Critically endangered** (IUCN) Facing a very high and immediate risk of extinction in the wild.

**Endangered** (IUCN) Facing a very high risk of extinction in the wild in the near future.

**The following categories are also used:**

**Vulnerable** (IUCN) Facing a high risk of extinction in the wild in the foreseeable future.

**Near threatened** (IUCN) Likely to qualify for one of the above categories in the near future.

**Conservation dependent** (IUCN) Dependent upon species- or habitat-specific conservation programs to keep it out of one of the above threatened categories.

**Data deficient** (IUCN) Inadequate information available to make an assessment of its risk.

**Not known** Not evaluated or little studied.

**Common** Widespread and abundant.

**Locally common** Widespread and abundant within its range.

**Uncommon** Occurs widely in low numbers in preferred habitat(s).

**Rare** Occurs in only some of preferred habitat or in small restricted areas.

**Fact file**
This profiles one or more of the illustrated species or groups, with information about its size, appearance, habitat, range, reproduction, migratory habits, behavior, calls, or regional variations.

**Distribution map**
This shows the species' or group's range (and former range, where appropriate). If distributed throughout the world, a world map is shown; if regional distribution, a map of that area only is given.

**Habitat icons**
The icons indicate the various habitats in which the profiled animal(s) can be found, for example coral reefs or rain forest. The full list can be found on the opposite page.

**Panel feature box**
Illustrations and text provide information about an interesting aspect of a species or group of species.

**Conservation symbols**
A red cross above the species' name indicates that it is extinct or extinct in the wild; a red flash indicates that it is critically endangered or endangered according to the IUCN Red List.

**Name labels**
Labels indicate the common and scientific names, as well as the species' family, order, or class, where appropriate.

**Labels**
The labels highlight distinguishing aspects or characteristics of the species, such as color variations, behavior, habitat, size, and anatomical features.

## FACT FILE STATISTICS

Important or interesting facts about that species or group, using the following icons and information. All measurements given are maximums

**Length**
- **Mammals:** head and body
- **Birds:** tip of bill to tip of tail
- **Reptiles:** snakes and lizards snout to vent; other reptiles head and body including tail
- **Turtles:** length of carapace
- **Amphibians:** head and body, including tail
- **Fishes:** head and body, including tail

**Height**
- **Mammals:** shoulder height
- **Birds:** head and body height

**Tail: Mammals**
- Length of tail

**Wingspan: Birds**
- From tip of one wing to tip of the other

**Weight/Mass**
- Body weight

**Social Unit: Mammal**
- Solitary
- Pair
- Small to large group
- Varies between the above

**Plumage: Birds**
- Sexes alike
- Sexes differ

**Reproduction: Birds and Reptiles**
- Number of eggs

**Migration: Birds**
- Migrant
- Partial migrant
- Sedentary
- Nomadic

**Habit: Reptiles and Amphibians**
- Terrestrial
- Aquatic
- Burrowing
- Arboreal
- Varies between the above

**Breeding season: Amphibians**
- When breeding occurs, e.g. spring

**Breeding: Reptiles and Fishes**
- Viviparous (producing live young)
- Oviparous (producing eggs that develop outside the maternal body)
- Ovoviviparous (producing eggs that develop within the maternal body)

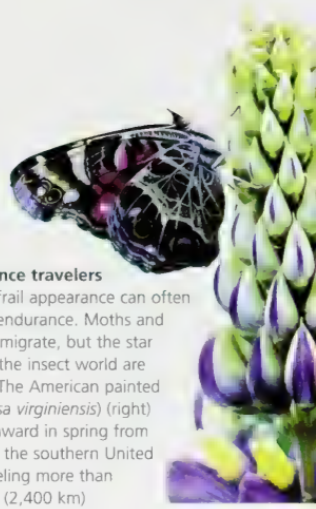
**Sex: Reptiles and Fishes**
- ♀♂ Reptiles: indicates whether a species is temperat[illegible] determined [illegible] sex determined [illegible] indicates separate male a[illegible] female, her[illegible] sequential [illegible]

**Number of genera and species: Birds, Reptiles, and Invertebrates**
The number of genera and sp[illegible] in the relevant taxonomic group

# ANIMALS

# THE ANIMAL KINGDOM

Animalia is one of five kingdoms into which biologists usually divide the living world. Monera includes bacteria and blue-green algae; Protista contains mostly large, unicellular organisms such as amoeba and paramecium, which were once considered animals but are now assigned to a kingdom of their own; molds, mildews, and mushrooms fall within the kingdom Fungi; and, as its name suggests, Plantae contains the plants. With more than 1 million of the 1.75 million living species currently described on Earth, kingdom Animalia is by far the largest and most diverse. It contains all the organisms most of us easily recognize as animals, as well as some species whose status would confuse many non-scientists. The overwhelming majority of animals are invertebrates—animals without a backbone. Among those, the insects dominate in terms of both individual numbers and species diversity. It is, however, the vertebrates with which most of us are familiar—fishes, amphibians, lizards, birds, and mammals—the group to which our own species is most closely affiliated in the evolutionary sense.



**Long-distance travelers**
A delicate, frail appearance can often belie great endurance. Moths and dragonflies migrate, but the star travelers in the insect world are butterflies. The American painted lady (*Vanessa virginiensis*) (right) heads northward in spring from Mexico and the southern United States, traveling more than 1,500 miles (2,400 km)

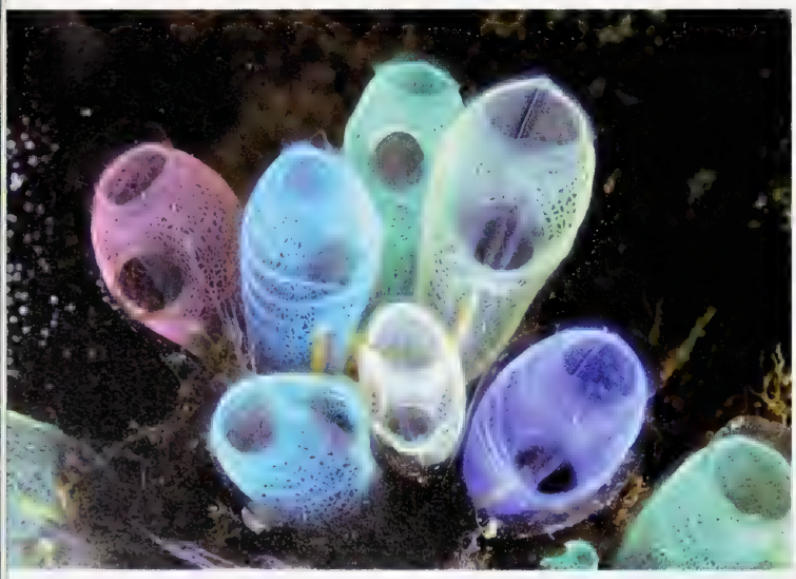
## DEFINING FEATURES

The kingdom Animalia is also often referred to as Metazoa, a term that indicates the multicellular nature of all its members. As in plants, the tissues of animals are always made up of eukaryotic cells. In animals, however, these lack cell walls. Instead, animal cells are held in place by an extracellular matrix that inevitably contains collagen and provides a mostly flexible framework within which the cells are organized.

Another key feature of all animals is that they are heterotrophs. Unlike plants, which are termed autotrophs, they cannot produce their own food and so, instead, must consume other organisms, either directly or indirectly, to get their nourishment. This has helped drive the extraordinary biodiversity seen among animals today and a vast range of ways to track, capture and consume food has evolved within the group.

Food requirements have also had an impact on animal body plans; most have some sort of centralized digestive system into which they take food and break it down.

The necessity for seeking out, or being near, food sources has also led to capabilities for movement. And, although, it is not always clear-cut, mobility separates most plants from most animals. Questions of mobility have caused confusion in the past among scientists about the status of some groups, in particular the sponges, the animals that have the longest evolutionary history. These are the only living animals that lack organization beyond the cell level



**Glued to the spot**

**Food for warmth** The brown bear (*Ursus

**Counting the species**
Scientists have described in the region of 1.75 million species of life-forms on Earth but that is thought to be only a small proportion of the true figure. Estimates place this at between 5 and 100 million species. Even the figures for the number of known species are hard to pin down because new species are being discovered all the time. Vertebrates (see chart at left) are the best-described group but make up only about 5 percent of animal species. There are about 1 million known species of insects but the true number could be more in the region of 30 million.

so that they have no organs or tissues, a unique feature that has added to past confusions about their status. Their cells are, however, capable of small movements, most have a free-swimming larval stage, and today there is no doubt they are animals and not plants.

The necessity and ability for independent movement has also helped impel in most animals the development of a nervous system with associated sensory equipment to coordinate and guide movements. Most also have body tissues, such as muscle, that facilitate movement.

Sexual reproduction is another unifying feature. Almost all animal species create offspring at some stage in their life-cycle by sexual reproduction; some have the capabilities to reproduce by asexual methods.

**Aerial agility** The range of the golden eagle (*Aquila chrysaetos*) extends over mountains and lowlands across the Northern Hemisphere. Most of its mammalian prey is taken on the ground from a low flight, but it is so agile and fast in the air that it will also take birds in flight. Some golden eagle pairs hunt together.

**Teamwork** Ants are members of a highly social family of insects. The collaborative efforts of leaf-cutter ants (*Atta cephalotes*) ensure there is a constant source of food. The ants bite off pieces of leaves, carry them underground, and then live on the fungi that subsequently forms on the plant matter and breaks it down.

**Building blocks** All life on Earth is made of cells. The first were prokaryotes—simple assemblages of genetic material within a cell wall. This structure is seen in bacteria. The development from prokaryotes to the mostly larger, far more complex eukaryotic cells underpinned the evolution of plants and animals. The genetic material of the eukaryotes is contained within a membrane-bound nucleus and separate organelles that perform specific metabolic functions.

# CLASSIFYING ANIMALS

Humans have a natural tendency to sort and organize. And it seems that, ever since the days of the ancient Greek philosopher Aristotle, we have been attempting to do just that with the many different living organisms with which we share the planet. Biologists have so far discovered, described, and assigned names to about 1.7 million species of plant, animal and microorganism that presently exist on Earth—a mere fraction of what the total number is thought to be. They have also named many species that lived in the past but have since gone extinct. Modern classification attempts, in part, to provide order and structure to the huge amount of information that has been gathered on different organisms. This is done by providing a unique name for each of these organisms and sorting them into hierarchies of increasingly exclusive groups, or "taxa," based on their evolutionary relationships. This allows for individual organisms to be unequivocally recognized while, at the same time, being associated with other organisms sharing a common ancestry. All classifications evolve and change with the gathering of more knowledge and new discoveries. In recent years, the capabilities to investigate and compare the DNA of organisms through genetic techniques have forced scientists to rethink the classification of many animals.

## SCIENTIFIC SORTING

Systematics is the name given to the science of discovering the diversity and evolutionary relationships of organisms. Aspects of systematics involved with naming and classifying organisms form the sub-discipline of taxonomy. The basic taxon, or group, for classification is the species. Ideally, all higher or more inclusive taxa comprise an ancestral species and all its descendants. Determination of this relationship is based on all members of a group sharing one or more derived features (evolutionary novelties).

## NAMING RIGHTS

Animals are known by different vernacular or common names that vary from language to language, country to country, and often even within the same country. And so, to avoid confusion, scientists use Latinized names for groups of organisms. This provides universality and stability and avoids the necessity of translating names into many different languages. In this way, no matter what one's native tongue, the Latinized scientific name is immediately associated with the same group of organisms.

The basic category in all classifications is the species. Species are populations of organisms that share one or more similarities not found in related organisms. Species also form closed genetic systems. This means that individuals can only reproduce sexually with another individual of the same species, although closely related species may occasionally hybridize.

**Close relations** Scientists have been witnessing and documenting behavioral and physiological similarities between humans and chimpanzees (*Pan troglodytes*) since before Darwin. In recent years, they have been able to compare the DNA of the two. Recent revelations that both share more than 98 percent of their genes have reinforced the view that they should be classified within similar categories.

**Linnaean classification** Each grouping [illegible]

**SPECIES:** *catus* – domestic cat

**GENUS:** *Felis* – domestic cat, sand cat, jungle cat, black-footed cat, Chinese desert cat

**FAMILY:** Felidae – domestic cat, lion, tiger, leopard, panther, puma, lynx, *Smilodon*

**ORDER:** Carnivora – domestic cat, seal, wolf, dog, bear, thylacine

**CLASS:** Mammalia – domestic cat, human, lemur, dolphin, platypus, woolly mammoth

**PHYLUM:** Chordata – domestic cat, fish, salamander, dinosaur, albatross

**KINGDOM:** Animalia – domestic cat, stick insect, sea urchin, sponge

**Common confusion** This South American insect (left) is known as both the pitbull katydid and the flat-headed katydid. Adding to the confusion, katydids are also called long-horned grasshoppers and bush crickets in North America, and the term tizi is sometimes used in Europe. Use of the taxonomic name assigned to this species, *Lirometopum coronatum*, avoids such issues of ambiguity.

**New discoveries** New invertebrates are still being discovered regularly, but it is rare to encounter previously undescribed mammal species. So it was unexpected when, late last century, the forests of Southeast Asia yielded three new species of small deer known as muntjacs.

## AN ENDURING SYSTEM

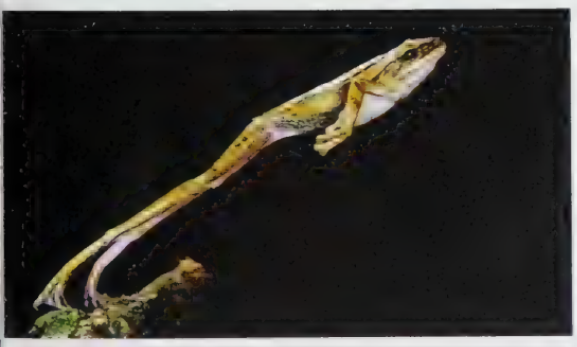
In the early 18th century, the Swedish naturalist Carl Linnaeus developed a scheme for naming, ranking, and classifying different organisms according to the presence or absence of observable similarities. His earliest version of this system was published in 1735 under the name *Systema Naturae*. Linnaeus went on to revise and refine it many times in his lifetime, and it has been developed and improved many times since. It still provides, however, foundations for the approach to classification now used by biologists throughout the world. As a result, Linnaeus is often referred to as the "father of taxonomy."

The principal feature of the Linnaean system, and one which continues to apply today, is that it assigns a unique two-part name to each and every different organism. In this so-called binomial system, the first part of the name indicates the genus to which the organism belongs. Known as the generic name, this indicates other organisms, both living and dead, with which the named organism shares its closest evolutionary relationships.

The second name is the specific name. Only one organism within any genus will ever be assigned this name. In this way, each organism receives its own unique two-part name. Scientists throughout the world know that when they use this name they are invariably talking about the same organism.

The generic name always begins with a capital letter, while the specific name is always written in the lower case. Both names are always printed in italics.

In instances when populations of a species are separated geographically and have relatively consistent differences, they may be recognized as a subspecies and assigned a third name. Like the species name, this is written in the lower case and also printed in italics.



**Leaping alike** All frogs and toads have one adaptation that sets them apart from other amphibians: the ankle bones are greatly elongated to form an extra segment in the hind leg, providing greater leverage for leaping. This is a distinguishing condition of the order Anura, within which all frogs and toads are placed. Frogs and toads also possess another adaptation to leaping; they have a short vertebral column with no more than 10 free vertebrae followed by a bony rod (the coccyx, representing fused tail vertebra).

**Looks can deceive** Evolutionary relationships are not always obvious from superficial anatomical features. Consider, for example, the African and Asian family of mammals known as hyraxes (right). All living species are roughly rabbit-sized and all look very much like rodents. But these animals are actually ungulates, or hoofed animals, and their closest living relatives are elephants and sea-dwelling manatees. Most species in one hyrax genus lead a primary existence in the trees, making them the only living hoofed animals to have an arboreal lifestyle.

## MAMMALS

The 26 orders of mammals are divided into three major groups based on the structure of their reproductive tracts. The most primitive are the egg-laying mammals with a single order, the monotremes. Marsupials, which give birth to young in a very early stage of development, are now considered to consist of seven orders. The other 18 orders are made up of placental mammals. The most recent evidence from DNA sequence analysis has revealed that whales and even-toed ungulates are more closely related to each other than to any other group. DNA also indicates that there have been three major radiations of placental mammals: in Africa, South America, and the Northern Hemisphere

**Class Mammalia**

EGG-LAYING MAMMALS
Order Monotremata
Monotremes

MARSUPIALS
Order Didelphimorphia
American opossums

Order Paucituberculata
Shrew opossums

Order Microbiotheria
Monito del monte

Order Dasyuromorphia
Quolls, dunnarts, marsupial mice, numbat, and allies

Order Peramelemorphia
Bandicoots

Order Notoryctemorphia
Marsupial moles

Order Diprotodontia
Possums, kangaroos, koalas, wombats, and allies

PLACENTAL MAMMALS
Order Xenarthra
Sloths, anteaters, and armadillos

Order Pholidota
Pangolins

Order Insectivora
Insectivores

Order Dermoptera
Flying lemurs

Order Scandentia
Tree shrews

Order Chiroptera
Bats

Order Primates
Primates

Suborder Strepsirhini
Prosimians

Suborder Haplorhini
Monkeys and apes

Order Carnivora
Carnivores

Family Canidae
Dogs and foxes

Family Ursidae
Bear and pandas

Family Mustelidae
Mustelids

SEALS AND SEA LIONS
Family Phocidae
True seals

Family Otariidae
Sea lions and fur seals

Family Odobenidae
Walrus

Family Procyonidae
Raccoons

Family Hyaenidae
Hyenas and aardwolf

CIVETS AND MONGOOSES
Family Viverridae
Civets, genets, and linsangs

Family Herpestidae
Mongooses

Family Felidae
Cats

Order Proboscidea
Elephants

Order Sirenia
Dugong and manatees

Family Trichechidae
Manatees

Family Dugongidae
Dugong

Order Perissodactyla
Odd-toed ungulates

Family Equidae
Horses, zebras, and asses

Family Tapiridae
Tapirs

Family Rhinocerotidae
Rhinoceroses

Order Hyracoidea
Hyraxes

Order Tubulidentata
Aardvark

Order Artiodactyla
Even-toed ungulates

*Family Cervidae, page 190*

Family Bovidae
Cattle, antelopes, and sheep

DEER
Family Cervidae
Deer

Family Tragulidae
Chevrotains

Family Moschidae
Musk deer

Family Antilocapridae
Pronghorn

Family Giraffidae
Giraffe and okapi

Family Camelidae
Camels and llamas

Family Suidae
Pigs

Family Tayassuidae
Peccaries

Family Hippopotamidae
Hippopotamuses

Order Cetacea
Cetaceans

Suborder Odontoceti
Toothed whales

Suborder Mysticeti
Baleen whales

Order Rodentia
Rodents

Suborder Sciurognathi
Squirrel-like rodents, mouse-like rodents, and gundis

Suborder Hystricognathi
Cavy-like rodents

Order Lagomorpha
Hares, rabbits, and pikas

Order Macroscelidea
Elephant shrews

## BIRDS

Since Charles Darwin, birds have been classified according to perceptions of their natural relationships. This approach clusters similar-looking, interbreeding populations in species—related or sister species in genera; sister genera in families; and sister families in orders—representing the "tree" of bird evolution.

We now identify species as similar-looking populations of organisms that can interbreed freely. Genera, families, and orders are based on structural similarities in limbs, skeletons, and feathers. Thus birds of the parrot family have a foot with two toes forward and two back, and a hooked bill with vertically twisted palate bones.

The accumulated data led the American Alexander Wetmore to devise a classification of the orders and families of birds in the 1930s. This epic work became the standard for bird classifications in the 20th century. Since then, DNA and other molecular studies have shown that many structural traits used for classifying birds are unreliable due to convergent evolution, especially within the families of passerines, or songbirds, which involve over half the world's bird species. In particular, they found that the wrens, flycatchers, robins, and warblers of Australasia were unrelated to Eurasian look-alikes. Modern research indicates that these Australasian groups are the old ancestral lineages of the world's songbirds, from Gondwana.

The bird classification used here takes account of these changes. At species, generic, and family levels, it is based on the most up-to-date and authoritative world checklist current, the Howard and Moore *Complete Checklist of Birds of the World*, published in 2003. That checklist did not consider orders; but here we have adapted its families to the familiar Wetmore arrangement.

**Class Aves**

Order Tinamiformes
Tinamous

Order Struthioniformes
Ostrich

Order Rheiformes
Rheas

Order Casuariiformes
Cassowaries and emus

Order Apterygiformes
Kiwis

Order Galliformes
Gamebirds

Order Anseriformes
Waterfowl

Order Sphenisciformes
Penguins

Order Gaviiformes
Divers

Order Podicipediformes
Grebes

Order Procellariiformes
Albatrosses and petrels

Order Phoenicopteriformes
Flamingos

Order Ciconiiformes
Herons and allies

Order Pelecaniformes
Pelicans and allies

Order Falconiformes
Birds of prey

Order Gruiformes
Cranes and allies

Order Charadriiformes
Waders and shorebirds

Order Pteroclidiformes
Sandgrouse

Order Columbiformes
Pigeons

Order Psittaciformes
Parrots

Order Cuculiformes
Cuckoos and turacos

*Order Apterygiformes, page 251*

*Order Pelecaniformes, page 271*

Order Strigiformes
Owls

Order Caprimulgiformes
Nightjars and allies

Order Apodiformes
Hummingbirds and swifts

Order Coliiformes
Mousebirds

Order Trogoniformes
Trogons

Order Coraciiformes
Kingfishers and allies

Order Piciformes
Woodpeckers and allies

Order Passeriformes
Passerines

*Order Passeriformes, page 324*

## REPTILES

Reptilia—living reptiles—traditionally includes turtles, crocodilians, tuatara, and squamates (lizards, snakes, and worm lizards). Crocodilians are most closely related to birds, but as birds are treated separately this section is assumed to cover non-avian reptiles. The position of turtles is in controversy; some studies show that the lineage of turtles is so distant from the squamates that they belong in a separate class. Lizards lost their limbs to become snakes or limbless lizards or amphisbaenians, so the formation of suborders within Squamata is controversial. Only the status of the tuatara as an ancient order by itself within the reptiles is agreed upon. The traditional separation of groups has been used, but the reader should be aware of the artificial nature of these groupings. The classification and names used for families, genera, and species generally follows the EMBL Reptile Data Base (http://www.embl-heidelberg.de/~uetz/LivingReptiles.html)

**Class Reptilia**

Order Testudines
Tortoises and turtles

Order Crocodilia
Crocodilians

Order Rhyncocephalia
Tuatara

Order Squamata
Lizards and snakes

Suborder Amphisbaenia
Worm lizards

*Order Testudines, page 358*

## AMPHIBIANS

Lissamphibia, the living amphibians, includes three orders: the frogs and toads (Anura), the salamanders, newts, and sirens (Urodela), and the caecilians (Gymnophiona). Amphibians are all derived from the same common ancestor (monophyletic). The main common feature all amphibians have is smooth skin without scales. The use of families, genera, species, and common names follows Amphibian Species of the World: an on-line reference (http://research.amnh.org/herpetology/amphibia/index.html). Other common names were sourced from regional guides or compendiums.

**Class Amphibia**

Order Caudata
Salamanders and newts

Order Gymnophiona
Caecilians

Order Anura
Frogs and toads

## FISHES

Any study of the fishes shows that they are an immensely diverse array of animals, differing greatly in the range of habitats they occupy and their body forms and adaptations. As a consequence, most biologists regard the term "fishes," as a convenient name, rather than a closely defined taxonomic entity, that describes aquatic vertebrates such as hagfishes, lampreys, sharks, rays, lungfishes, sturgeons, gars, and the advanced ray-finned fishes. There are a number of classification schemes for the fishes but one of the most widely accepted recent ones recognizes five classes of living species and three classes that are now extinct. The five classes, whose classification is detailed below, are hagfishes, lampreys, cartilaginous fishes, lobe-finned fishes, and ray-finned fishes. These are grouped into two superclasses: jawless fishes and jawed fishes. The three extinct classes are the pteraspidomorphs—jawless armored fishes, the jawed placoderms that were encased in bony plates, and the acanthodians, small true bony fishes with two long dorsal spines.

JAWLESS FISHES
Superclass Agnatha
Lampreys and hagfishes

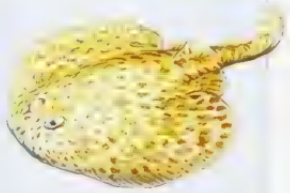
*Superclass Agnatha, page 453*

JAWED FISHES
Superclass Gnathostomata
(includes all the groups below)

CARTILAGINOUS FISHES "Chondrichthyes"
Class Chondrichthyes
Sharks, rays, and allies

Subclass Elasmobranchii
Sharks
Rays and allies

Subclass Holocephali
Chimaeras



*Subclass Elasmobranchii, page 462*

BONY FISHES "Osteichthyes"

Class Sarcopterygii
Lungfishes and allies

Class Actinopterygii

Subclass Chondrostei
Bichirs and allies

Subclass Neopterygii

Primitive Neopterygii
(gars and bowfin)

Division Teleostei

Subdivision Osteoglossomorpha
Bonytongues and allies

Subdivision Elopomorpha
Eels and allies

Subdivision Clupeomorpha
Sardines and allies

Subdivision Euteleostei
(includes all the groups below)

*Subdivision Osteoglossomorpha, page 472*

Superorder Ostariophysi
Catfish and allies

Superorder Protacanthopterygii
Salmons and allies

Superorder Stenopterygii
Dragonfishes and allies

Superorder Cyclosquamata
Lizardfishes and allies

Superorder Scopelomorpha
Lanternfishes

Superorder Polymixiomorpha
Beardfishes

Superorder Lampridiomorpha
Opahs and allies

Superorder Paracanthopterygii
Cod, anglerfishes, and allies

Superorder Acanthopterygii
Spiny-rayed fishes

*Acanthopterygii, page 498*

## INVERTEBRATES

Over 95 percent of all animals are invertebrates. They are characterized by a structure that they all lack: a backbone or vertebral column. Invertebrates are divided into about 30 phyla, each displaying a distinct body form. Their evolutionary relationships can be inferred from their anatomy, their early development, and more recently from molecular analyses, particularly DNA, the genetic code. Features that define phyla include the organization of the body from a loose association of cells (Porifera), through tissue formation (Cnidaria) to the development of organs (Platyhelminthes) The acquisition of a fluid-filled body cavity was a defining point in animal evolution that allowed animals, such as Nematoda, Annelida, and many other phyla of worms, to move about by an hydraulic system driven by fluid pressure. The origin and form of these body cavities characterize different phyla. While these phyla are soft-bodied, others are protected and supported by various types of skeletons, such as shells in Mollusca and a jointed exoskeleton in Arthropoda. The division of the body into segments allowed for specialization of parts of the body. In arthropods, this has led to the development of segmental appendages that carry out specific functions, such as sensory perception, feeding and locomotion. Details of early embryonic development divide many advanced phyla into two lineages, one leading through the Echinodermata to the Chordata, the phylum to which vertebrates belong, the other containing the bulk of animal phyla. While molecular analyses have confirmed many of our ideas about the course of evolution based on anatomy and development, there are a number of instances where they are at variance. Hence, our classificatory system is undergoing revision. Furthermore, the continual identification of new species of invertebrates indicates that we are nowhere near their full inventory, and certainly far from understanding their vital roles in the sustainability of ecosystems.

*Phylum Cnidaria, page 520*

Phylum Chordata
Invertebrate Chordates

Subphylum Urochordata
Sea squirts

Subphylum Cephalochordata
Lancelets

Phylum Porifera
Sponges

Phylum Cnidaria
Cnidarians (sea anemones, corals, jellyfishes, etc.)

Phylum Platyhelminthes
Flatworms

Phylum Nematoda
Roundworms

Phylum Mollusca
Mollusks (bivalves, snails, squids, etc.)

*Phylum Mollusca, page 525*

Phylum Annelida
Segmented worms

Phylum Arthropoda
Arthropods

Subphylum Chelicerata
Chelicerates

Class Arachnida
Arachnids

Class Merostomata
Horseshoe crabs

Class Pycnogonida
Sea spiders

*Class Arachnida, page 536*

Subphylum Myriapoda
Myriapods (centipedes, etc.)

Subphylum Crustacea
Crustaceans

Subphylum Hexapoda
Hexapods

Class Insecta
Insects

*Order Odonata, page 554*

Order Odonata
Dragonflies and damselflies

Order Mantodea
Mantids

Order Blattodea
Cockroaches

Order Isoptera
Termites

Order Orthoptera
Crickets and grasshoppers

Order Hemiptera
Bugs

Order Coleoptera
Beetles

Order Diptera
Flies

*Order Coleoptera, page 563*

Order Lepidoptera
Butterflies and moths

Order Hymenoptera
Bees, wasps, ants, and sawflies

Order Embioptera
Webspinners

Order Dermaptera
Earwigs

Order Thysanura
Silverfish

*Order Lepidoptera, page 570*

Order Phasmatodea
Stick and leaf insects

Order Archaeognatha
Bristletails

Order Raphidioptera
Snakeflies

Order Ephemeroptera
Mayflies

Order Megaloptera
Dobsonflies and alderflies

Order Phthiraptera
Parasitic lice

Order Psocoptera
Book lice and bark lice

Order Siphonaptera
Fleas

Order Thysanoptera
Thrips

Order Neuroptera
Lacewings, antlions, and allies

Order Mecoptera
Scorpionflies

Order Plecoptera
Stoneflies

Order Trichoptera
Caddisflies

Order Zoraptera
Angel insects

*Order Siphonaptera, page 580*

Order Grylloblattodea
Rock crawlers

Order Strepsiptera
Strepsipterans

Class Collembola
Springtails

Class Protura
Proturans

Class Diplura
Diplurans

Phylum Echinodermata
Echinoderms (sea stars, sea urchins, sea cucumbers, etc.)

*Phylum Echinodermata, page 583*

Phylum Nemertea
Ribbon worms

Phylum Entoprocta
Goblet worms

Phylum Tardigrada
Water bears

Phylum Ctenophora
Comb jellies

Phylum Rotifera
Rotifers (wheel animals)

Phylum Hemichordata
Hemichordates (acorn worms)

Phylum Chaetognatha
Arrow worms

Phylum Gastrotricha
Gastrotrichs

Phylum Kinorhyncha
Spiny-crown worms

Phylum Phoronida
Horseshoe worms

Phylum Onychophora
Velvet worms

Phylum Brachiopoda
Brachiopods (lamp shells)

*Phylum Rotifera, page 586*

Phylum Bryozoa
Bryozoans (lace animals)

Phylum Sipuncula
Peanut worms

Phylum Echiura
Spoon worms

Phylum Loricifera
Brushheads

Phylum Priapulida
Phallus worms

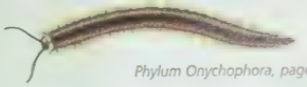
Phylum Nematomorpha
Horsehair worms

Phylum Acanthocephala
Spiny-headed worms

Phylum Pogonophora
Beard worms

Phylum Gnathostomulida
Sand worms

Phylum Cycliophora
Cycliophorans



*Phylum Onychophora, page 587*

Phylum Placozoa
Placozoans

Phylum Orthonectida
Orthonectids

Phylum Rhombozoa
Rhombozoans

# EVOLUTION

Questions of how and where life began have fascinated and confounded people for millennia, giving rise to creation myths and legends in all human cultures. Scientifically, the answers continue to be debated and are unlikely ever to be known for certain. There are, however, two things upon which scientists tend to agree: that all life on Earth shares common ancestral origins; and that the crucial events that led to life's earliest precursors probably occurred more than 4 billion years ago. At that time, Earth would have been just hundreds of millions of years old and mostly ocean. It would have been a fiercely inhospitable place with high ultraviolet light levels, violent electrical storms, intense volcanic activity, and an atmosphere containing very little oxygen but dominated by methane, hydrogen, and ammonia. However unlikely it may seem, it was from this hostile cradle that life first emerged. And slowly, over the ensuing billions of years, it was the appearance of life itself, and all the processes that this requires, that helped to slowly transform the planet.

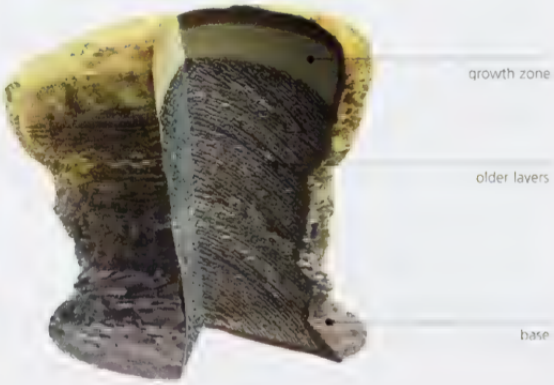
## IN THE BEGINNING

The most popular scientific theory on the origin of life is that it began with simple organic molecules, upon the likes of which all life is built, arising spontaneously from inorganic compounds contained in Earth's early environment. How this might have occurred was first suggested by a famous experiment carried out in the early 1950s by biochemists Stanley Miller and Harold Urey at the University of Chicago. Within a laboratory simulation of Earth 4 billion years ago, they produced organic building blocks common to all life, including amino acids and nucleotides.

Aggregations of such molecules are thought to have led to the first cells. These may have been similar to the types of non-air-breathing bacteria that cause fermentation today. The oldest evidence of such cells, found in ancient rocks in Greenland, indicate such organisms would have formed before 3.5 billion years ago. The next crucial step required cells to harness the energy of the Sun.

**Evidence of past life** The fossil record provides consistent support for the theory of evolution as an explanation for the ascent of life on Earth. Most people think of fossils as bones, or the shapes of bones, preserved in rock, soil, or sediment However, a fossil is any physical evidence of plants or animals from the ancient past These prehistoric artefacts of life have been recovered from all continents

**Living fossils** At 3.5 billion years of age, stromatolites are the world's oldest known fossils. These ancient reef-building structures were formed mainly by photosynthesizing colonial cyanobacteria, also known as blue-green algae, believed to have been Earth's dominant life form for about 2 billion years. Stromatolites were built vertically in layers as mats of the bacteria trapped minerals and sediment grains New bacterial colonies grew up toward the light upon each successive layer. This process continues in Shark Bay in Western Australia, one of only two locations in the world where living stromatolites still occur



## REVOLUTIONARY THEORY

Eventually, some of those early cells developed the ability to photosynthesize, using energy from sunlight to produce their own food in the form of simple sugars. Importantly, that process released oxygen as a by-product. As oxygen gradually accumulated in the atmosphere, another type of cell, the eukaryotic cell, appeared. Evidence of metabolic activity by such cells found recently in rocks in northwestern Australia indicates these had arisen by 2.7 billion years ago. It is this type of cell that ultimately gave rise to all multicellular life, both plant and animal.

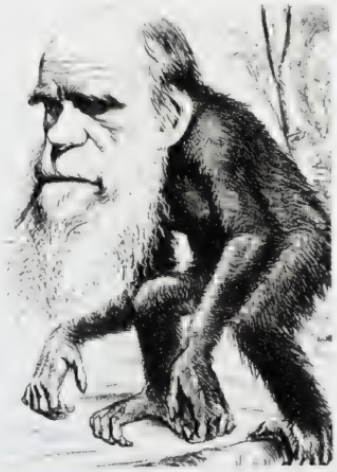
Until late last century, the oldest known fossil proof of animal life dated to almost 600 million years ago. However, in 1998 researchers announced the discovery of what is believed to be evidence of animals that existed much earlier—trails known as "trace fossils" thought to be created about 1 billion years ago by worm-like creatures in bottom sediments of an ancient sea that once covered India.

Regardless of when life of any type first appeared, most scientists agree that its diversification into the billions of different forms that have since appeared is a product of evolution. The core concept of evolution—that similar species share similar ancestries—harks back to ancient Greek philosophers. But the formal theory of evolution, as we now know it, was set down in 1859 by English naturalist Charles Darwin in his book *On the Origin of Species by Means of Natural Selection*. The theory is now seen as a crucial development in science and remains pivotal to virtually all biological research. It has been refined and developed since it was first published, but its basic tenets, which propose that different species appear in response to changing conditions, still hold.

Ever since Earth formed some 4.5 billion years ago, its environments have been changing. According to evolutionary theory, those organisms that successfully adapt, persist. Those that cannot, perish. This process later became known as "survival of the fittest." Darwin's theory posits that organisms that are better adapted to their surroundings are more likely to persist over time than those that are not; as a result, they have greater opportunities to produce descendants. These, in turn, are likely to carry and pass on the same traits that helped their parents survive.

Overwhelming evidence for evolution, and the mechanisms of natural selection that drive it, has come from the fossil record. The theory is also rigorously supported by comparisons between species, both surviving and extinct, in the areas of anatomy, embryological development, and, more recently, gene biochemistry.

**Brave new work** Darwin's theory of evolution was condemned by many church followers in the deeply religious England of the mid-1800s. Darwin was ridiculed in caricatures and cartoons (below), and became embroiled in controversy because his theory challenged the mainstream thinking of the day on the genesis of Earth and its life-forms. The public was particularly outraged by what Darwin's work insinuated about human origins, although this topic was specifically avoided in the original publication of his theory.



### CONTINENTAL DRIFT

Until the early 1900s, it was widely believed that the continents held fixed positions. But by the 1960s, extensive geological, palaeontological, and biological evidence suggested ancient connections between continents and indicated that these land masses were still drifting inches (cm) apart annually. It is thought that about 300 million years ago, all the present-day continents were joined in the one large supercontinent known as Pangea. This huge land mass began separating about 200 million years ago to create two great continents. Biological similarities between past species preserved in the fossil record as well as between present-day species support evidence that Australia, India, Africa, South America, and Antarctica were once part of a southern supercontinent known as Gondwana. Similarly, Asia, North America, and Europe were once joined in a northern land mass, known as Laurasia.

**Cephalopod evolution** Nautiluses are the most ancient of the surviving cephalopods. Their ancestry can be traced back more than 500 million years to the Cambrian. The group was once considerably more diverse than it is today and included giant, fiercely predatory, straight-shelled species that may have filled ecological roles later taken over by shark

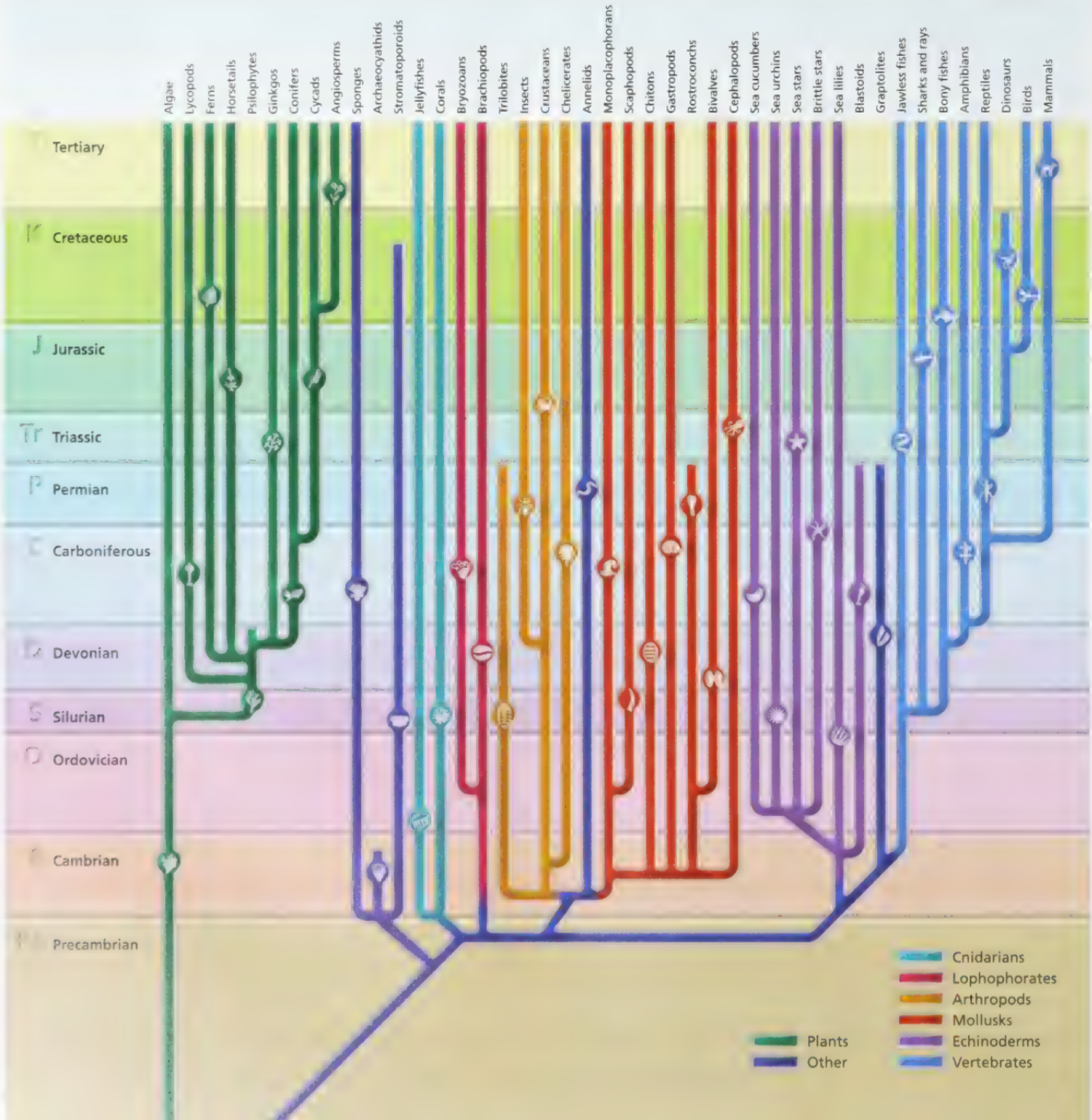
**Natural selection in action** [illegible]

## LIFE IN PERSPECTIVE

Earth's history is documented in vast intervals of time, and repeatedly punctuated by sequences of organisms that have evolved and gone extinct. It is a record that, if anything, reveals the insignificance of our species compared with what has preceded us and what will inevitably follow.

The history of modern humans (the species *Homo sapiens*) spans just over 100,000 years—a mere speck on a time-line covering more than 4 billion years.

Evidence of significant events in Earth's history comes largely from geology and palaeontology, and inevitably involves the sophisticated dating and interpretation of rocks and fossils. Most animal fossils have been recorded from the last 600 million years, since the beginning of the Cambrian period. Many of Earth's geological periods that have occurred since then are characterized by the animals that dominated them. The Jurassic, for example, is often referred to as "the age of dinosaurs" because these creatures reigned supreme during that time, in terms of both total numbers and species diversity. That gave way to the "age of mammals;" however, as the geological record repeatedly reveals, dominance does not always ensure survival.



## SEXUAL EVOLUTION

Without sex, evolution would not exist, because the opportunities for change and adaptation that underpin natural selection require the genetic variation that is provided by sexual reproduction.

The first form of reproduction was undoubtedly asexual: the simple splitting of cells into daughter cells, as is still seen in today's single-celled organisms. Many "primitive" multicellular organisms such as worms and sponges can reproduce asexually through "budding," or regeneration from body cells or tissues. Slightly more advanced multicellular animals use the asexual process of parthenogenesis to produce offspring from unfertilized eggs. Asexual reproduction allows for rapid increase in numbers, but individuals are almost always genetically identical.

Sexual reproduction probably arose some 1.5 billion years ago and became the dominant, and usually only, form of reproduction in higher animals. Sexually produced organisms carry half the genes of each parent, usually in a unique combination. Thus, within any given species, a range of genes will be available for adaptations to a changing environment. When genes are advantageous, the species persists and/or eventually gives rise to a new species. Other genes may be benign or irrelevant; disadvantageous genes can cause a species to die out.

**Budding "babies"** The phylum Cnidaria, which includes corals, jellyfishes, hydroids, and sea anemones, is one of the few phyla in which asexual reproduction occurs commonly. Budding among species in the genus *Obelia* (above left) results in genetically identical individuals. In colonial species such as corals, individuals remain attached, creating branching tree-like organisms joined with a common flesh

**Reproductive success** Each generation of a species represents a slightly new range of genetic combinations. Thus, any group or species with rapid reproductive rates—such as many of the insects—will be better equipped than less prolific breeders to deal with changing environments. This partly explains why insects have representatives in virtually every available terrestrial habitat

**Populate or perish** Sexual reproduction works better for some species than others Those with low reproductive rates, such as the giant Galápagos tortoise (*Geochelone elephantopus*) (below), survive well in stable environments. But this species is not coping with recent rapid change (such as introduced competitors and predators) on the Galápagos archipelago, and its future is now threatened

## WHEN SPECIES DIE

Today, the extinction of a species invariably evokes widespread anger and sadness, rightly so, most people would argue, because extinctions documented in very modern times (that is, the past few hundred years) have invariably occurred as a direct result of human activity.

But extinction is not necessarily a dirty word. It is in fact a natural part—indeed, a consequence—of evolution. More than 99 percent of the species that have ever evolved on Earth—estimated to number at least 2 billion—have gone extinct. Those that survive today—perhaps as many as 30 million, although less than 2 million have so far been identified and described—represent a tiny fraction of the species that have gone before them.

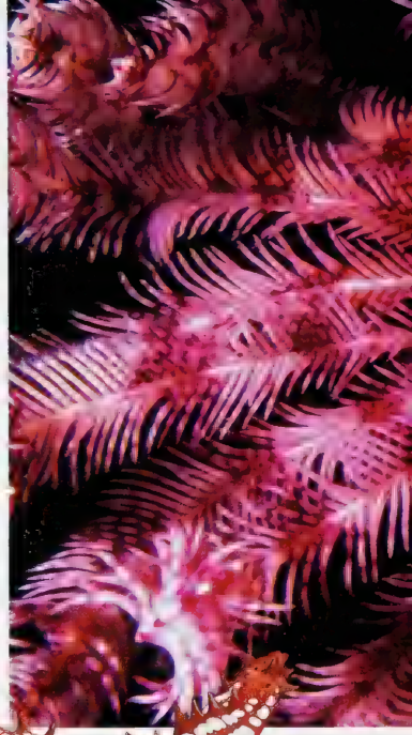
The evidence, particularly from the fossil record, suggests that most species exist for between 1 million and 5 million years before dying out. It is highly likely, however, that many species live for considerably shorter periods of time. There are also many that manage to survive longer. Such species that are still alive today are often referred to as "living fossils." Examples include the coelacanths, two ancient fish species believed to have appeared more than 65 million years ago. Remarkably, one of these remained undiscovered until the late 1990s.

## EXTINCTION EN MASSE

Under "normal" circumstances, scientists believe that between one and 10 species would be dying out annually due to the natural forces of evolution. This is known as the background extinction rate. At various times during Earth's long geological history, however, that rate has been considerably higher, indicating a period of "mass extinction."

The fossil record suggests that at least five mass extinctions have occurred to date, the last—and one of the biggest—at the end of the Cretaceous period, about 65 million years ago. More than three-quarters of all species alive at the time, including the last of the dinosaurs, disappeared forever. Likely reasons for mass extinctions have included large-scale climate change, huge meteors hitting Earth, and intense geological activity.

These extinctions occurred over many thousands or, in some cases, millions of years. There is widespread concern that we are currently experiencing a sixth mass extinction, proceeding at a faster and more intense rate than any before, caused by human activity.

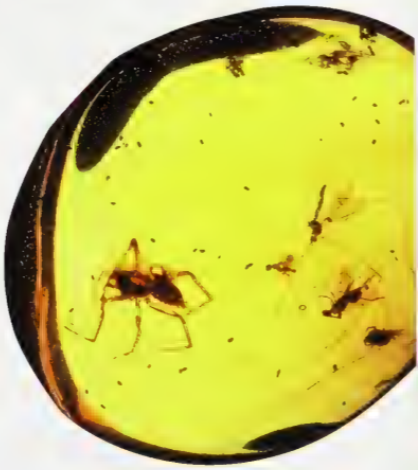


**Convergent evolution** Sometimes animals evolve under such similar conditions that they develop comparable anatomical modifications, making them seem more closely related than they really are. For example, penguins (left) and auks were once mistakenly thought to share recent ancestral origins. Both live in cool oceanic environments and are flightless, with flipper-like wings well adapted for underwater swimming. Penguins, however, are confined to the Southern Hemisphere and are most closely allied to petrels and albatrosses. Auks are strictly Northern Hemisphere relatives of puffins and gulls. The warm waters of the tropics are thought to have kept the two groups apart for many millennia.

**Resisting desiccation** The development of the amniotic egg occurred first in the reptiles and was critical in the colonization of land by vertebrates and their pervasive penetration of terrestrial environments. A series of fluid-filled sacs cushion the developing embryo within a calcareous shell that is permeable to gases, such as oxygen and carbon dioxide, but which restricts water loss.

**Distant relations** Echinoderms such as crinoids (left) and starfish are thought to be more closely related to humans than their appearance might suggest. This group of exclusively marine organisms is considered an evolutionary offshoot of the line from which rose the chordates, a group which contains all the vertebrates. The association is suggested by similarities in early embryonic development

**Amber** The bodies of insects and spiders easily become distorted and crushed, so they are very poorly represented in the traditional fossil record. Their features survive much better when preserved in fossil tree resin known as amber (below) Other small animals such as centipedes and lizards, as well as plants, have been found preserved in amber, the most significant deposits of which are found in sands lining the shores of the Baltic Sea



## EARLIEST ANIMALS

Although the fossil record indicates that multicellular animals first appeared on Earth much earlier, the oldest "complete" fossils come from about 600 million years ago, toward the end of the Precambrian. They belong to a group of soft-bodied marine organisms known as the Ediacaran fauna, evidence of which was found in 565-million-year-old rocks in the Ediacaran Hills, in South Australia's Flinders Ranges, in the 1940s. Since then, similar fossils have been found on all continents except Antarctica.

Ediacaran fauna included many bizarre animals unlike anything known from other times. Other forms were reminiscent of worms, jellyfishes, arthropod-like creatures, and organisms that looked like large sea-pens, similar to those seen within the phylum Cnidaria.

The relationship between the Ediacaran animals and those that have appeared on Earth since is unclear. Some scientists believe they were predecessors of groups that came later. Others consider them an evolutionary dead-end: a natural history "experiment" that ended without leading onto anything else.

## CAMBRIAN EXPLOSION

Before the discovery of the Ediacaran fauna and the recognition of their significance, the oldest known complete fossils of multicellular animal life came from the Cambrian. This period is still known and celebrated for the explosion of life, exclusively marine, that suddenly appears in the fossil record in rocks from this time: an abrupt and huge rise in biodiversity, the scale of which has not been known since. Ancestors of almost all major living animal phyla appear in the fossil record for the first time during the Cambrian, mostly within a period spanning just 40 million years. Of particular significance is the earliest evidence of hard shells and exoskeletons, the evolution of which may have been partly driven by a rise in predatory species.

Long-since-extinct trilobites, early forms of arthropod with unusually well-developed eyes, proliferated. So, too, did sponges. Other distinctive Cambrian fauna included large, burrowing, worm-like predators known as echiurans. Echinoderms were also plentiful and represented by several large classes. However, it is believed that only one from that time, Class Crinoidea, still survives today.

Both gastropod and cephalopod mollusks are represented in fossils from the Cambrian, but these groups did not reach their heyday until later. The earliest chordates, ancient ancestors of our own species and all other vertebrates, also appeared during this period.

In addition, there were also many strange life forms that do not appear to be directly allied to any known group. One of the most famous was *Wiwaxia*. A small bottom-dweller, up to 2 inches (5 cm) long, *Wiwaxia* had a body covered by plate-like armor and rows of spines. Beneath this, it is believed to have been slug-like, but its relationship to any living animal group remains unclear.

*Wiwaxia* is known from the most famous and extensive Cambrian fossil deposits, at a site known as the Burgess Shale, located within British Colombia's Yoho National Park in the Canadian Rocky Mountains. The site was first identified in 1909, and was given World Heritage status in the early 1980s. More than 60,000 fossils have been recovered from these deposits. Some of them are so exquisitely well preserved that it is possible to determine their stomach contents and details of muscles and internal organs.

**Dinosaur demise** Climate change following a collision between Earth and a vast meteor remains the most widely supported theory on why the dinosaurs, among them *Triceratops* (below), went extinct. Evidence of dinosaurs disappears from the fossil record at about the same time that geological proof of such an impact appears

**Mostly terrestrial** Behavior can provide clues to the origins and evolutionary affiliations of living species. Adult red crabs (*Gecarcoidea natalis*) live almost exclusively in burrows on the floors of rain forests on Christmas Island, in the Indian Ocean. Each year, however, they migrate en masse (left) to cliffs where females cast fertilized eggs into the ocean, their ancestral home. Larvae develop there for up to 4 weeks before returning to land as juveniles.

**Avian enigma** The evolutionary lineage of South America's hoatzin (*Opisthocomus hoazin*) baffled scientists for more than 200 years. Unlike any other bird, the hoatzin ferments plant matter in a foregut, as cows do. Wing claws, used by young to climb trees, are reminiscent of those of the famed prehistoric *Archaeopteryx*. Its morphology suggests an ancestry tied to pheasants and chickens. Recent genetic investigations, however, finally confirmed it to be most closely related to cuckoos.

## BEYOND THE CAMBRIAN

The fossil record provides evidence of two Cambrian creatures that could have been, or were probably very much like, the direct ancestor of the vertebrates. Small fish-shaped filter-feeders similar to modern-day lancelets, *Pikaia* (from the Burgess Shale deposits, in Canada) and *Cathaymyrus* (found in southern China) are the oldest known fossil chordates. The first vertebrates are thought to have arisen from such creatures just after the close of the Cambrian, about 480 million years ago. They were jawless fishes, known as Agnathans, with mainly benthic lifestyles. They were, in many cases, protected from predators by heavy armor-like plates.

The first cartilaginous fishes, sharks, had appeared by the late Ordovician. The origins of the bony fishes—now the most diverse group of vertebrates—show a little later in the fossil record, around the late Silurian, just over 400 million years ago. By the Devonian, the fishes proliferated to such an extent that this period is often referred to as "the Age of Fishes."

Just before this—toward the end of the Silurian, about 420 million years ago, and shortly after vascular plants emerged on land—the first animals began moving out of the oceans and into terrestrial habitats. These were arthropods, whose hard external skeleton (which may have evolved initially as protection against predators) proved valuable in restricting water loss. Arachnids and centipedes would have been among the earliest terrestrial forms of this group, which went on to become one of the planet's most successful.

## LAND VERTEBRATES

The move by vertebrates onto land was preceded by the evolution of lobe-finned bony fishes (the Sarcopterygii) in the early Devonian. By the middle of that period, a group of sarcopterygiians known as rhipidistians are thought to have begun using their fleshy fins to clamber around the bottom of shallow, warm, oxygen-depleted waters and probably even on land for brief periods. These fishes shared features in common with both modern lungfishes (among the few surviving sarcopterygiians) and amphibians. And it is likely they, or fishes very similar to them, gave rise to the first amphibians about 380 million years ago, near the end of the Devonian.

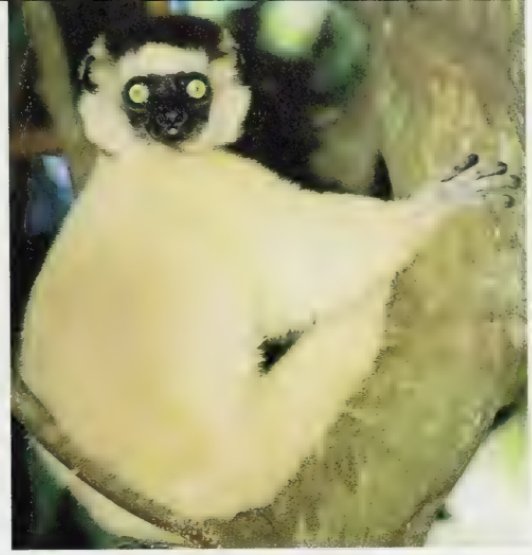
It is thought the first reptiles—probably small insectivores—evolved from amphibian ancestors very quickly, in evolutionary terms, within the next 30 million years. At that time, Earth was warm and humid. As the climate began to get considerably drier—about 280 million years ago, at the start of the Permian—reptiles began to diversify. By 275 million years ago, mammal-like reptiles had appeared. They became the dominant land vertebrates for a short period, but most disappeared by around 230 million years ago.

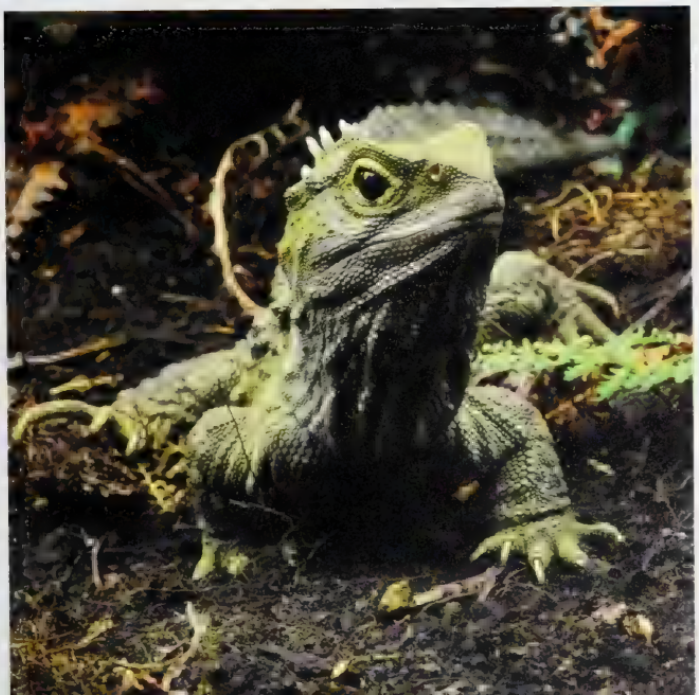
However, around 220 million years ago, one of the remaining groups of these reptiles, the cynodonts, gave rise to the first mammals. At about the same time, amphibians similar in form to modern frogs and salamanders also emerged. Crocodiles and turtles first appeared around this time too, as did the dinosaurs.

***Indricotherium*** This type of giant hornless rhinoceros, which became extinct about 25 million years ago, may have been the largest mammal ever to walk the Earth. Adults attained heights of about 18 feet (5.5 m) at the shoulder and weights in excess of 15 tons (13.6 metric tons).

**Land-loving fish** Watching mudskippers "climbing" trees on mudflats (left), it is not [illegible] how the early colonization of land may have proceeded. However, [illegible]

**Adaptive radiation** When a species arrives or appears in a new habitat to which it is well suited but where it faces little competition, it may undergo a rapid type of evolution known as adaptive radiation. This occurred in the lemurs (below, right, and below right), a group of primitive primates known only from the Indian Ocean island of Madagascar. The ancestral lemur is thought to have left its biological competitors on the African mainland about 55 million years ago and to have arrived on the island on a natural raft. Finding no rivals with similar requirements, it rapidly and repeatedly evolved into a unique group that is now represented by more than 30 surviving species, each of which occupies its own slightly different ecological niche, and some of which have adaptations to deal with preferred prey





**Living fossils** Two species of tuatara, *Sphenodon punctatus* and *S. guntheri*, are the only survivors of a large group of reptiles that was widespread around the world during the Triassic, more than 225 million years ago. Most became extinct about 60 million years ago. Fossil evidence shows the relict tuatara species, which are now confined to small islands off New Zealand, have changed little since their early evolution. Current populations stand at some 400 *S. guntheri* and more than 60,000 *S. punctatus*.

**Ancient aeronauts** Odonata, to which dragonflies and damselflies belong, is one of the oldest surviving insect orders Some of the earliest dragonflies had wingspans of up to 3 feet (1 m) Flapping flight was unlikely. Instead it is believed they were gliders with limited capability for aerial maneuvering. Wings emerged very early in insect evolution and are believed to have developed from gill-like organs

## DINOSAURS RULE

The earliest dinosaurs were small bipedal carnivores. The group diversified quickly, and by the end of the Triassic, 206 million years ago, many herbivorous forms had appeared. Some had already begun to approach the massive sizes for which these animals are renowned. The radiation of dinosaurs coincided with the appearance and global spread of coniferous trees, which are thought to have been the main food source for the largest of the dinosaurs.

For 150 million years, dinosaurs dominated the planet, the last disappearing 65 million years ago as part of the mass extinction at the end of the Cretaceous. Around the middle of this extraordinary reign, the first birds are thought to have arisen from small, bipedal, carnivorous dinosaurs called theropods. It is believed that feathers first evolved not for flight, but warmth.

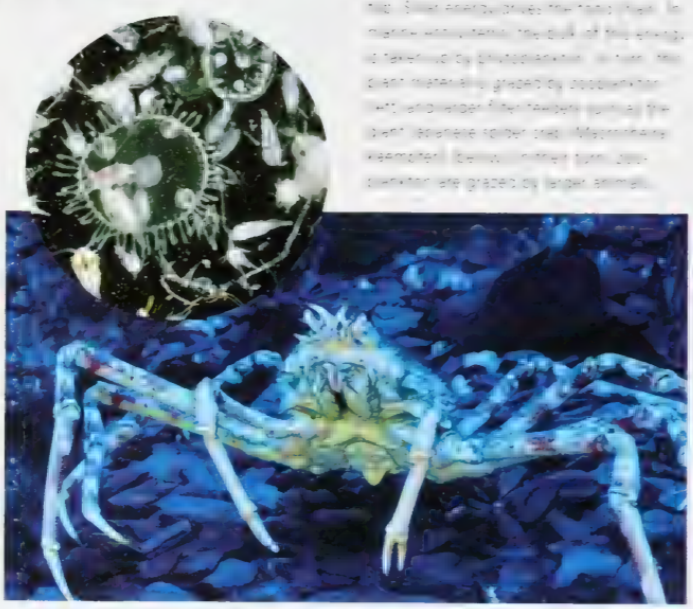
## MAMMALS RISE

Mammals first appeared about the same time as the earliest dinosaurs, but early mammalian radiation is thought to have been inhibited by the rise of the latter. As a result, the mammals diversified and evolved relatively modestly at first, with most species remaining nocturnal and small—about the size of today's shrews and mice—for millions of years. Once competition from, and predation by, the dinosaurs ended, mammals flourished and diversified.

One important and largely tree-dwelling genus that appeared just before the Cretaceous mass extinction, and survived it, was *Purgatorius*. It is thought that within this group was the ancestor that ultimately gave rise to modern primates, including our own species, which probably first appeared just over 100,000 years ago.

# BIOLOGY AND BEHAVIOR

All animals share basic survival requirements such as the need to respire, eat, and find shelter, and they meet these by using a combination of biological and behavioral responses. Such strategies are frequently consistent between different groups across the animal kingdom. This enables identification of biological and behavioral blueprints—patterns that are often constrained by the universal laws of physics—that are revisited repeatedly within and between different groups of animals. For example, all animals take in oxygen via a thin, moist surface. This occurs over the entire outer body in many worms; across thin gill filament folds in most fishes; and in lungs in all of the land vertebrates.



**Food chains** There is far more biomass at the bottom of a food chain than at the top. Since energy drops the more it ascends, the bulk of this energy is harvested by photosynthesizers, in turn, this plant material is grazed by zooplankton (left, enlarged). Filter feeders pump the plant-laden water into Mesoamericana kaemofeldi (below), in turn, zooplankton are grazed by larger animals.

## SIZE MATTERS

There are good reasons why huge insects and other arthropods are the stuff of science fiction. One is the fact that they have a hard external skeleton. To grow, arthropods must molt: the exoskeleton is shed to allow expansion of the body within before a new exoskeleton is formed. This leaves soft tissues unsupported against gravity during each of the growth periods.

The bigger an animal, the greater the gravitational force exerted upon it. Gravity would collapse oversized insects into a heap during molting. As a result, the largest arthropods inhabit aquatic environments, where they are supported by water.

Gravity also helps to define the upper size limits of mammals, so it is no coincidence that the biggest mammal and largest animal ever, the blue whale (*Balaenoptera musculus*), is oceanic. It attains lengths of more than 110 feet (33.5 m) and weights of almost 209 tons (190 tonnes) because water helps to support its massive bulk.

In a large mammal, the ratio between body surface area and volume is low. Because small animals have higher surface-area-to-volume ratios, they lose heat faster. Larger mammals, consequently, tend to be found in colder climes while the smaller species proliferate closer to the tropics. For similar reasons, species of polar animals such as seals, penguins, and the musk ox (*Ovibos moschatus*) usually have compact extremities—including legs, ears, and snouts—to keep their surface-area-to-volume ratio as low as possible.

**On a small scale** Smaller mammals need [illegible]

**Gain without pain** Although it may [illegible]

**Battle of the giants** Mating among seals is controlled by a small group of dominant males, with a single male controlling up to 50 females on a small stretch of beach. Dominant males often inflate their noses and produce a noise that sounds like a drum to warn lesser males away. Conflict of a more physical nature occurs between males such as the northern elephant seals (*Mirounga angustirostris*) right, when a territory is seriously threatened or the male seeks to displace an established male.

## SEX WARS

All species are innately impelled to pass on genes to future generations. Most achieve this transfer through sexual reproduction, which involves the meeting of sperm and eggs.

Hermaphroditism is a reasonably widespread phenomenon among animals, but more often sex cells are contained within separate males and females, and many biological and behavioral adaptations have evolved to ensure that reproduction occurs among the fittest individuals. These animals are the best adapted to the environment and, therefore, the ones most likely to contain the genes that ensure the survival of their species.

In many instances, males prove their reproductive worth by battling one another and this is one reason males are frequently larger than the females of their species. This has also driven the evolution of male combat equipment such as horns and antlers in species as diverse as rhinoceros beetles and deer. Behavioral displays are often important, particularly among mammals, to avoid or reduce the severity of aggressive encounters so that the combatants are not left dead or disabled from battle.

## FANFARE AND DEMONSTRATION

In some species, the males secure reproductive rights by proving their genetic fitness directly to prospective mates, and have evolved physical and behavioral displays specifically for this purpose. This underlies the spectacular colors, adornments, and elaborate courtship displays that are common among the males of many bird and some fish species.

There are many other strategies that males deploy in order to attract females. Male bower birds construct impressive arches of grass decorated with collections of small offerings aimed at influencing the decision of prospective mates. In a similar way, male stickleback fishes build nests to win female attention.

Some males demonstrate their genetic fitness to mates by providing gifts—usually offerings of food. This tactic is common among insects and some spiders. With the latter, the offering is usually the male himself. It is thought that consuming the gift distracts the female spider from mating with other males, while also providing nutrients that will give her offspring a good start at life.

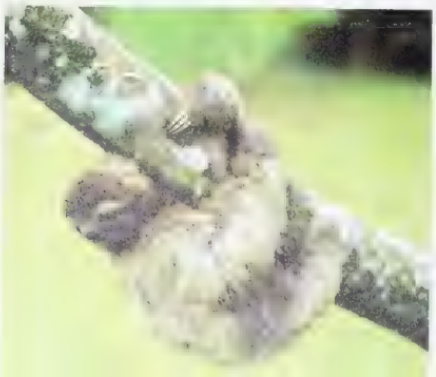
Among birds, courtship feeding is used by the males of some species to show their paternal capabilities for finding food for offspring.

**Armed and dangerous** The rhinoceros beetle (*Xylotrupes australicus*) uses its horns in its battle for territory and, ultimately, a mate. The horns are very strong, enabling the beetle to forage through heavy leaf litter on the forest floor or dig a burrow.

**Show time** Usually it is the male bird that plays the lead role in courtship by showing off his plumage to duller-colored females. Possibly the most stunning fanning display is that of the male Indian peacock (*Pavo cristatus*). The radial alignment of feathers in the semi-circular fan requires the root of each one to be pointed with an acute degree of precision. Remarkably, they are put into position by muscles in the male's tail. Not only can he display the feathers, but he can make them vibrate and hum.

**Tooth and claw** A lioness (*Panthera leo*) brings down a zebra (*Equus burchelli*), risking lethal injury from the equid's flying hooves as she does so. Despite the danger, zebras are a mainstay in the diet of lions on the East African savanna.

**Tree dweller** The maned three-toed sloth (*Bradypus torquatus*) is both a slow eater and a slow digester of food. As much as a month may pass before foodstuffs finally pass from the multichambered stomach to the small intestine.



## YOU ARE WHAT YOU EAT

Diet influences metabolism and activity levels and can in some cases provide protection against predators. For example, by eating certain ants, South American poison-arrow frogs (*Dendrobates* sp.) produce a toxin in their skins to which only one snake species is known to be immune.

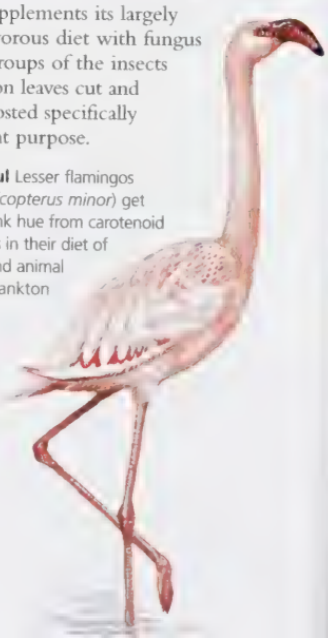
Diets that are of low nutritional value typically produce slow-moving, lethargic animals. Tropical rain-forest-dwelling three-toed sloths consume mainly plant matter with a high level of cellulose that is difficult for them to digest. A slow metabolism, low body temperature, and the habit of sleeping for up to 18 hours a day help them to survive on this low-energy diet. In Australia, the koala displays similar physiological and behavioral adaptations to a low-energy diet that is comprised of large amounts of leaves from a few species of eucalypts.

## EAT OR BE EATEN

The most readily recognizable physical and behavioral features of animal species often relate directly to the need to locate and consume food as efficiently as possible. Most carnivorous mammals, such as the big cats of the African savanna, have large, sharp teeth designed to rip and tear tough flesh, lightning-fast reflexes, and capabilities for rapid acceleration. Herding behavior provides the grazing herbivores on which they prey, such as zebras and gazelles, with a safety-in-numbers response. Also, these herbivores have evolved hooves that can deliver a harmful blow, and keen senses of sight and smell.

Many of the most acute feeding adaptations are seen among those animals with specialist diets. The long tongues and curved bills of honeyeaters, for example, are the ideal design for the extraction of high-energy nectar from flowers. And the South American leaf-cutter ant supplements its largely herbivorous diet with fungus that groups of the insects farm on leaves cut and composted specifically for that purpose.

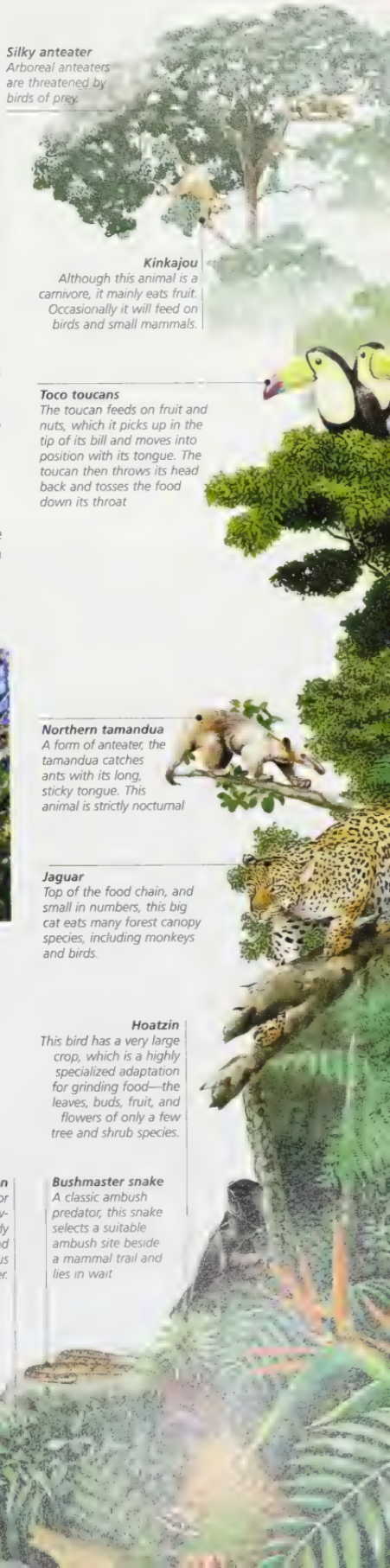
**Colorful** Lesser flamingos (*Phoenicopterus minor*) get their pink hue from carotenoid proteins in their diet of plant and animal microplankton.



**Rain-forest food chain** As with other food chains, in a South American rain forest (right), there is far more diversity and a greater number of species at the bottom end of it than there is at the top. The most stable forest environment is found at ground level. Here, wind seldom penetrates and temperature, humidity, and ambient light levels rarely change. Along the chain, predator and prey wage a constant battle for biological superiority, pushing each other into more and more evolutionary developments.

**Silent killer** Like other owl species, the great gray owl (*Strix nebulosa*) swoops unheard on its prey. Its outer flight feathers have a jagged edge, which slows the flow of air over their wings, minimizing the noise made as they flap. Most flying birds' flight feathers have smooth edges.

**Boom or bust** Locusts are usually solitary insects. But when food is abundant, they may band together in huge swarms, some containing several billion insects, and then take to the air en masse. The scourge of farmers, locusts wreak havoc, destroying vast fields of grain in a few hours.



***Silky anteater***
*Arboreal anteaters are threatened by birds of prey.*

***Kinkajou***
*Although this animal is a carnivore, it mainly eats fruit. Occasionally it will feed on birds and small mammals.*

***Toco toucans***
*The toucan feeds on fruit and nuts, which it picks up in the tip of its bill and moves into position with its tongue. The toucan then throws its head back and tosses the food down its throat*

***Northern tamandua***
*A form of anteater, the tamandua catches ants with its long, sticky tongue. This animal is strictly nocturnal*

***Jaguar***
*Top of the food chain, and small in numbers, this big cat eats many forest canopy species, including monkeys and birds.*

***Hoatzin***
*This bird has a very large crop, which is a highly specialized adaptation for grinding food—the leaves, buds, fruit, and flowers of only a few tree and shrub species.*

***Bird-eating spider***
*As an adult, this spider is large enough to devour small birds. It also eats lizards, beetles, and small snakes*

***Vegetation***
*The forest floor has a slow-growing woody shrub layer and a herbaceous ground layer.*

***Bushmaster snake***
*A classic ambush predator, this snake selects a suitable ambush site beside a mammal trail and lies in wait*

## BREAKING IT DOWN

Whether they do so directly or indirectly, all animals ultimately derive nutrition from plants. Herbivores are not, however, the main consumers of vegetation. Rather, a vast amount is eaten by the decomposers, which include burrowing earthworms and insect larvae.

There are also many animals such as flies and beetles that play a role in the decomposition of animal flesh in land habitats. And, in aquatic environments, crustaceans such as crabs, scavenging fishes, filter-feeding zooplankton and bottom-dwelling anemones, starfishes, and other invertebrates, all contribute directly to breaking down organic matter.

The role of decomposers is critical to the survival of all living things, because their actions release minerals and nutrients and make them available to be recycled in food webs.

## WHEN IS ENOUGH ENOUGH?

In the case of many herbivores, the simple answer to this question is never. When compared with flesh, vegetation is low in nutrients such as protein. It is also hard for most animals to digest because they do not produce the enzymes necessary to break down the tough cellulose that commonly strengthens plant-cell walls. Herbivores have evolved ways to overcome these challenges. They spend the majority of their time eating, and have long, complex intestines in which symbiotic bacteria break down cellulose.

Nevertheless, even the most efficient herbivores swallow large quantities of vegetation that pass through them undigested. An adult African elephant, for example, is unable to digest more than half of the several hundred kilograms of vegetation that it consumes daily.

Because flesh is higher in nutrients than plant matter and easier to digest, carnivores have relatively short intestines and feed less frequently. The white shark (*Carcharodon carcharias*), a fierce oceanic predator, is one of many carnivores believed to need only one large meal every few days.

## IN ATTACK AND DEFENSE

The eternal conflict between prey and predator has underpinned the evolution of key adaptations in many animals. Camouflage is a common strategy; it helps to hide predators while hunting, and is also used by prey seeking concealment.

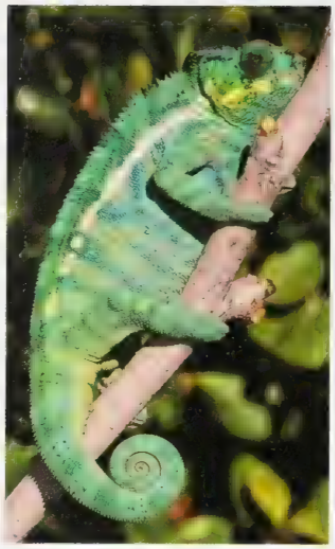
Spines keep birds from eating some caterpillars, just as they deter dingoes from eating echidnas. Prey animals that are poisonous are often brightly colored to warn of their toxic flesh and unpalatability. To deter predators, some animals that are not toxic even mimic the markings of those that are.

Predators, too, may use mimicry. Anglerfishes dangle worm-like baits in front of their mouths. Some snakes use the tips of their tails in a similar way to attract prey.

## GETTING AROUND

Every animal species is capable of movement during some part of its life. Exactly how depends on where it lives and its reasons for moving. Almost all fishes, for example, have the ability to swim, but torpedo-shaped pelagic species that chase their food are invariably faster and more agile than those that sit and wait for prey in ocean sediments.

Marine mammals, of course, are all proficient swimmers. But a surprising number of terrestrial mammals can also swim well when they need to. More often, however, they move by walking, running, crawling, or jumping. A few tree-dwellers, such as possums and squirrels, can glide. However, bats are the only mammals that can fly as proficiently as most birds.



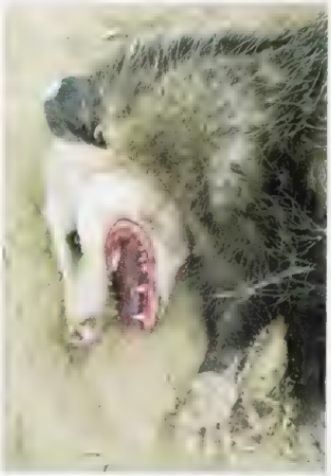
Some animals change their mode of movement at different stages of their life-cycle. Many tadpoles, for example, lead free-swimming lives until metamorphosing into hopping adult frogs or toads.

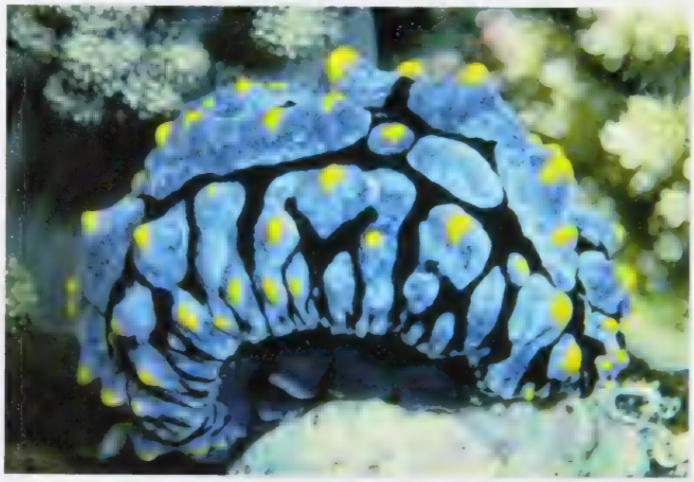
**Quick change** Chameleons are famed for their highly developed camouflage, which, combined with their leaf-like shape, is especially useful when slowly stalking prey. Chameleons may also change color in threat displays (such as from one male to another) or when they are disturbed.

**Cheetah hunting** Cheetah generally hunt in open terrain, choosing a victim then pursuing it to the exclusion of all others, even those nearer or more available. Chases seldom last more than 20 seconds; such a burst of speed requires tremendous amounts of energy and builds up massive amounts of heat, so that the cat soon finds itself overheated and out of breath.

**Playing possum** When faced with danger, opossums (right) commonly become comatose and appear dead. The opossum will lie on its side, become stiff, and drool. Its eyes will glaze over and its tongue will roll out of its mouth. This response, which is entirely involuntary and may last as long as 4 hours, helps the opossum survive an attack, as many predators will give up if it [illegible] that the opossum is already dead.

**Nudibranch feeding on coral** Many nudibranchs (far right) are brightly colored [illegible] predators that they are [illegible]. Others are subtly [illegible] camouflage. Many nudibranchs [illegible]





**On the hop** Macropods such as the red kangaroo (*Macropus rufus*) have large powerful hindlimbs and long hindfeet that enable them to hop fast, using their long and rather inflexible tail for balance. This is a very energy-efficient form of locomotion: a hopping kangaroo uses less energy than a four-legged animal of the same size moving at the same speed. However, this specialization has meant that kangaroos and wallabies are unable to walk. When moving slowly, they raise their hindquarters on a tripod formed by the forelimbs and the tail, then swing both hindlegs forward at the same time

**From tree to tree** Flying squirrels glide rather than fly, using a membrane down each side of the body (the patagium) as a parachute and the tail as a rudder Direction is controlled by the legs, tail, and the stiffness of the paragium. Before landing, the squirrel brakes by flexing its body and tail upward

## IN THE FAST LANE

The ability to move fast is a boon for predators. Much of the physiology of the cheetah (*Acinonyx jubatus*) is built for speed—from its streamlined body; long, powerful legs; large nostrils, lungs, heart, and liver; to its long rudder-like tail and feet designed to improve traction. Clocked at top speeds of about 70 mph (112 km/h), no other land animal is faster. Its favored prey, gazelles (*Gazella* sp), are swift, but cannot outrun cheetahs. They often, however, outmaneuver them.

The fastest swimmers are sailfish (*Istiophorus* sp.), pelagic carnivores that prey on other fishes and cephalopods. They have been recorded at speeds of about 68 mph (110 km/h).

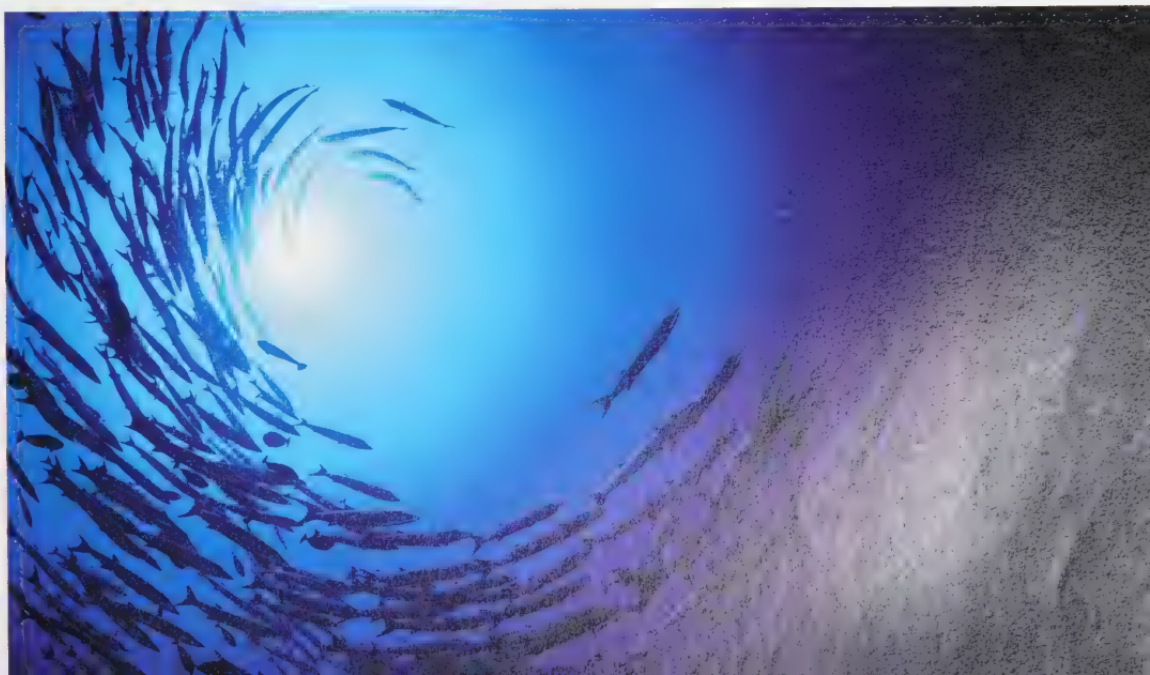
The peregrine falcon (*Falco peregrinus*) can achieve a similar pace when in horizontal flight. However, it has been shown to travel at up to 273 mph (440 km/h) when plummeting to swoop on prey.

Limbs are not always necessary for rapid movement. The venomous black mamba (*Dendroaspis polylepis*), an East African snake, can slither, with its head and front body raised off the ground, to speeds of about 7 mph (11 km/h).

## FINDING THE WAY

Scientists have only recently begun to understand the navigational tools that animals use to guide their movements. Bees use polarized light to navigate according to the sun's position during daily foraging forays. Birds, too, probably use the sun as a guide on long migrations, but the Earth's magnetic field is also thought to play a role. The latter is thought also to be important to migrating whales; they probably also recognize visual landmarks close to coastlines. Animals as diverse as salamanders and rodents use scent trails for short distances. Scent is probably also an important aid to marine turtles looking for nesting beaches.

***Flying squirrel***
*Certain species of squirrels and possums have developed a form of non-powered flight known as volplaning. They may glide for 150 feet (46 m) or more from tree to tree*



**Swimming machines** Barracuda such as the blackfin (*Sphyraena genie*) are designed for maximum hydrodynamic efficiency. The body is streamlined, and has grooves and depressions into which the fins can be tucked away to reduce turbulence While barracuda do not hunt cooperatively, they will frequently attack schools of prey en masse, breaking up the school structure so that individual fishes are easily captured

## LIVING TOGETHER

Animals can gain many advantages by living with other members of the same species. There are many tasks in which a group approach can make life considerably easier, such as watching out for and fighting off predators, and finding, hunting for, or gathering food.

Many birds live in simple family groups with a monogamous adult pair raising chicks from year to year. Single-parent families are also common among birds as well as mammals. In these situations it is usually the female, rather than the male, that remains in close association with the offspring until they become mature enough to fend for themselves.

Extended families are formed when different clutches or litters of offspring stay on with their parents after reaching maturity, sometimes even helping them to raise the next generation. The most extreme examples are among the social insects, such as bees and termites, which live in large groups with complex divisions of labor. The naked mole rat (*Heterocephalus glaber*) is the only mammal known to have a similar social structure.

## EXTERNAL RELATIONS

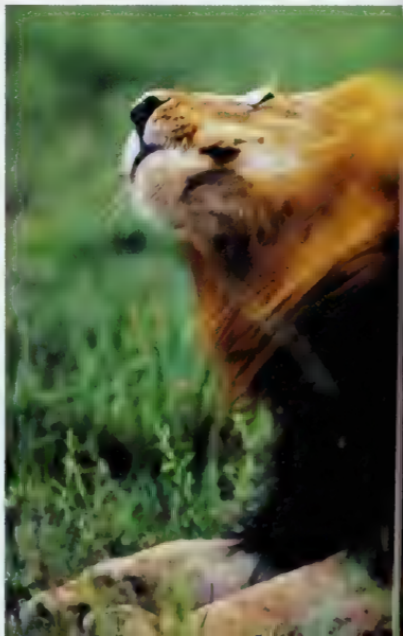
Many animals form close relationships with other species, with which they have often evolved in tandem. An association that benefits both parties is called mutualism. For example, oxpeckers (*Buphagus* sp.) obtain nutrition by picking parasites from the skin of grazing herbivores such as zebra (*Equus* sp.). In return they act as early warning signals, flying up into the air and screeching at the approach of a predator.

In situations of commensalism, only one species benefits, while the other is unaffected. Remoras gain protection and food scraps by living in association with large fishes, which neither gain nor lose anything from the relationship.

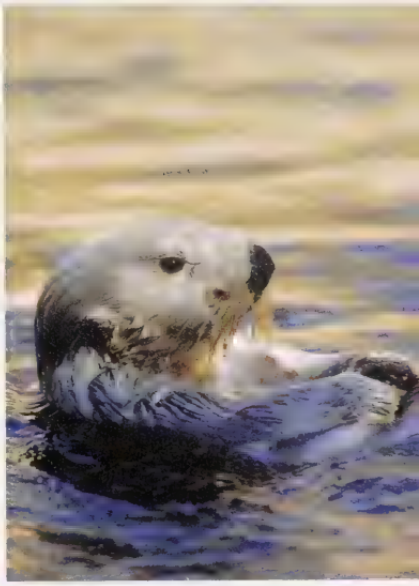
In parasitic relationships, one party, the host, is deleteriously affected, sometimes even killed.

**Group living** Mandrills (*Mandrillus sphinx*) live in troops of a few to several dozen animals. The young learn about selecting and preparing food by observing their mothers. In this way, group traditions in food preference develop. Adults will also prevent juveniles from eating unfamiliar food. Like other social primates, mandrills use various forms of touch, including grooming, to cement social bonds

**Cubs beware** Lions (*Panthera leo*) live in prides of five to 15 adult females and their offspring, and one to six adult males Newly installed dominant males usually kill all cubs sired by previous males. The absence of cubs prompts the females to come into season and to mate with the new male. Infanticide thus improves the chances of survival for the new male's cubs



**Mutual benefit** Some animals that would normally be potential prey for another species gain its protection by offering a useful service. Although all moray eels are carnivorous, they do not eat cleaner shrimp, instead relying on the shrimp to remove parasites (left). In return, the shrimp gets both food and protection, as the eel's presence deters other predators.



**At home in the sea** The sea otter (*Enhydra lutis*) is the only marine mammal to use tools, hammering mollusks with a stone to break the shell and extract the flesh. It dives for its food, feeling with agile forefeet for mollusks and crustaceans such as clams, sea urchins, abalone, crabs, and mussels. Most dives last a little more than 1 minute, although some otters can stay down for up to 5 minutes. The otter stores its prey in loose skin folds at its armpits, then surfaces to eat, or to breathe and dive again. A social animal, it lives in sex-segregated groups, known as "rafts," of a few to a couple of hundred animals.

## LEARNING POWER

All animals are born with innate capabilities, responses, and adaptations, which are known collectively as instinct. Many, however, also have some capacity to learn. Even some invertebrates are capable of the simplest form of learning, known as habituation. This involves the reduction in a reflex as a response to repeated but inconsequential stimulation. For example, the marine snail (*Aplysia californica*) will retract its siphon (which is used to expel waste matter) in response to touch. When repeated touching has no negative effect, reflex retraction of the siphon ceases.

Through conditioning, an animal learns to anticipate a consequence in response to a stimulus. A bird, for example, will recognize and avoid individuals of a particular caterpillar species if it has already tried to eat one and found it distasteful.

Animals living within well-defined social structures often have strong capabilities for trial-and-error learning. This occurs when an animal learns, often through repeated mistakes, the most advantageous way to perform a particular behavior. Many young animals learn survival skills in this way through play. They also learn vital lessons by watching and imitating a parent or other elder.

## CULTURAL RELATIONS

Through imitation, some animal populations transfer learned skills between individuals and even generations so that they develop a form of culture. Animals in which this has been recognized include primates, cetaceans, and elephants. A famous example, documented in the 1950s, occurred within a macaque troop living on a small island off Japan. Scientists fed the monkeys sweet potatoes. One monkey washed its potato in water to remove the dirt. Within a short time, all the monkeys were doing this, and it became an entrenched behavior among that troop.

There are also many examples of chimpanzees developing tools, such as sticks to extract termites from mounds, and then passing on the skill to peers and offspring.

**Interlopers** Cuckoos are famed for their habit of laying eggs in the nests of other species, such as a sedge warbler (below) However, only about 50 of the 130-odd species are truly parasitic. In some parasitic species, the cuckoo's single young pushes other eggs or chicks out of the nest; in others, the young cuckoos out-compete the host's hatchlings for food and they die Cuckoos' eggs often mimic those of the host, and different females within one species of cuckoo may each be adapted to parasitize one species of host

## HAVING AN IMPACT

Many animals have a profound influence—be it beneficial or deleterious—on the environments in which they live. For example, earthworms' actions break down vegetative material, thus improving soil fertility. Swarming locusts, however, can reduce or destroy an area's productivity by stripping vegetation before moving on.

Elephants can be similarly destructive in their pursuit for food, often pushing over entire trees to reach the most succulent leaves.

Beavers can create an even more significant effect through their dam-building, by changing the nature of the water flow in streams and rivers.

## UNDER CONSTRUCTION

Although beavers are the best-known builders in the animal world, many other species have impressive construction skills. Among the most accomplished avian nest-builders are African weaver birds, the males of which carefully interlace and knot grass stems and leaves into huge structures with several entries.

Many insects construct shelters and traps, but the supreme insect builders are termites. The mounds of some species can be 30 feet (9 m) tall and house millions of insects.

## CALLING CARDS

By emitting chemical signals known as pheromones, animals can leave behind or transmit messages to other members of their species. Recipients use their sense of smell, and sometimes also taste, to detect these signals

Pheromones often produce a behavioral response among recipients and can sometimes even have a physiological reaction. For example, a pheromone produced by the queen in honey-bee hives suppresses female workers' reproductive systems and stimulates drones to mate with the queen only. Chemicals in the urine of queens in naked mole rat colonies are thought to perform a similar function.

## RECEIVING AND SENDING MESSAGES

All of the five basic senses that humans have—sight, touch, taste, smell, and sound—also function throughout the animal kingdom. Only with the senses of hearing and sight are humans as many ants, for example, appear to touch to the same way the legs of spiders detect vibrations. And, like the antennae of many moths, they can also detect chemical messages in a sense akin to smell.

The range of perception of sense organs also varies. Elephants and cetaceans, for example, can perceive and communicate by deep rumbling infrasound undetectable to the human ear. Certain animals, such as canids and sharks, are able to follow scent trails so faint that they are undetectable to humans. Likewise, the visual capacity of animals that rely on sight can vary significantly between different animal groups.

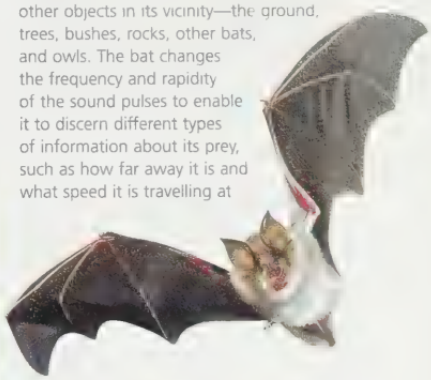
Animals also have senses for which humans have no equivalent. Fishes, for example, have lateral lines, systems of jelly-filled canals under the skin that are connected to the outside by open pores. These perceive tiny pressure changes in the surrounding water, which indicate the presence of an object or another animal

## ECHOING

Echolocation has evolved independently several times in the animal kingdom. Bats, toothed whales, porpoises, and some birds use this elaborate form of sonar to navigate, to locate and capture prey, and for social interactions. Even some mammals, such as shrews and tenrecs, use a basic form of echolocation to find their way in lightless conditions.

An animal using echolocation will emit sounds, such as clicks in dolphins and squeaks in bats, that are beyond the range of human hearing. It then interprets the angle and quality of the echoes that bounce off solid objects nearby. The frequencies used range from about 1,000 hertz in birds; 30,000 to 120,000 hertz in bats; and at least 200,000 hertz in whales.

**Seeing in the dark** To be able to chase and capture prey in the dark, a bat such as this greater horseshoe bat (*Rhinolophus ferrumequinum*) uses echolocation. This enables it to simultaneously recognize all other objects in its vicinity—the ground, trees, bushes, rocks, other bats, and owls. The bat changes the frequency and rapidity of the sound pulses to enable it to discern different types of information about its prey, such as how far away it is and what speed it is travelling at

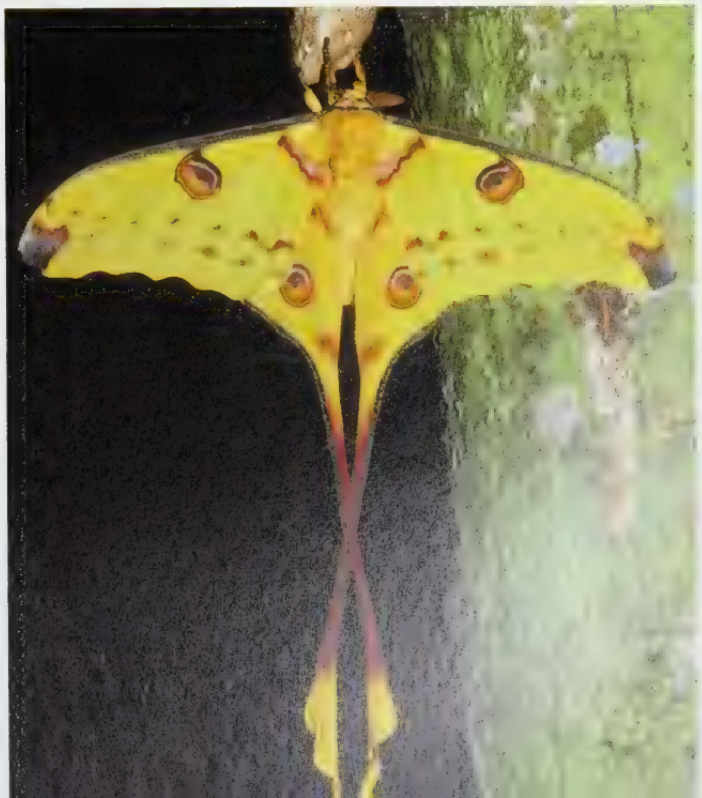


**Warning signal** Rattlesnakes, such as the northern Pacific rattlesnake (*Crotalus viridis oreganus*), have the tip of the tail modified into a warning device, the rattle, which is formed of specially shaped dry scales. When the tail is vibrated, the segments move against each other to create a buzz

**Attracting and repelling** Like most moths, the African moon moth (*Argema mimosae*) releases pheromones as signals to other moths. In general, female moths release pheromones to attract males from a distance, while males do so only when close to a female, to sexually stimulate her. As with most insects, scent detection is performed by the antennae. Some moths also emit ultrasounds, which interfere with the echolocation of predatory bats

**House proud** Males of most bowerbird species build and decorate elaborate structures that are neither nest nor shelter, but exist only to impress females. The type of bower and its decorative scheme are species specific, with most species having distinct color preferences. The western bowerbird (*Chlamydera guttata*) (left) builds two parallel walls of sticks; others build platforms or mats. But the greatest avian architect is the Vogelkop bowerbird (*Amblyornis inornatus*), which builds a maypole-like structure up to 5 feet (1.5 m) high. Males devote most of their time to building and decorating their bowers

**Good and bad impacts** When food is scarce, African elephants (*Loxodonta africana*) can devastate large areas by pushing over trees to reach the topmost twigs. However, they play a pivotal role in their ecosystem in various other ways: by dispersing seeds and distributing nutrients through their dung; by providing water by digging waterholes that other species use; and by enlarging existing waterholes when bathing and wallowing. They make paths, usually leading to waterholes, which act as firebreaks. Also, they provide protection for other species, as their height enables them to see far and warn of danger



# HABITATS AND ADAPTATIONS

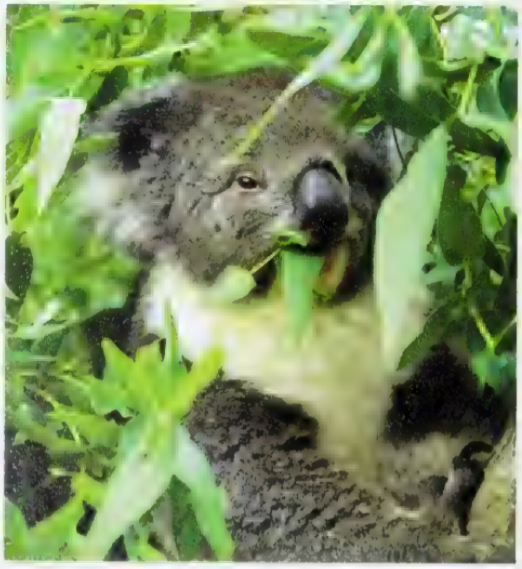
Habitats are the locations or surroundings in which living organisms survive. They are the providers of food, shelter, and other fundamental requirements necessary for plants and animals. Different habitats are most often characterized by a combination of their climate and geography but sometimes also by the communities of species that dominate them. Coral reefs, for example, occur in shallow and mostly tropical oceanic waters in which the coral polyps have laid down their calcium-carbonate skeletons. Different forest types, however, are defined by combinations of characteristics such as their latitude, total rainfall, whether the rainfall is received consistently throughout the year or in a marked season, and the dominant vegetation.

## BETWEEN WORLDS

While most species exist within one habitat, there are many that exploit or regularly move between more than one. Emperor penguins huddle together on ice in Antarctic breeding colonies during the bitter polar winters but feed on fishes in open oceanic waters long distances away. Migrating species, too, often move between habitats to exploit or avoid different or changing conditions. Within habitats, animals function in ecological niches. This defines the roles that animals play and includes what they eat, what eats them, where they find shelter, where they find food, and how they respond to and interact with other organisms. Some species are adapted to a very specific niche with a narrow range of parameters. Koalas, for example, survive only where their food trees—specific eucalypt species—grow.

Other animals such as some cockroach pest species have more generalist adaptations and are able to operate within wide niches or across several niches.

**Natural vegetation** This map shows the vegetation that would occur naturally without human interference. Climate and soil determine the vegetation of an area, and the vegetation, in turn, determines the extent and diversity of animal life. Together, the plants and animals of each zone form an ecological community known as a biome. The rainfall and warmth of the tropics have given rise to the greatest biodiversity in the world. In addition to the terrestrial zones indicated, freshwater and marine biomes contain abundant, diverse life-forms. The oceans, for example, are home to life-forms ranging from minuscule plankton to giant whales.



**Tree dweller** The koala (*Phascolarctos cinereus*) builds neither nest nor den. For this marsupial, eucalypts provide both a home and a food source. The species of eucalypts that the koala eats have a high fiber and cellulose content as well as [illegible] concentrations of toxic compounds. The koala must chew on large quantities [illegible] to obtain sufficient nutrients.

**Hibernating hedgehog** Hibernation [illegible]

## DEMARCATION ISSUES

The line where one habitat begins and another ends is not necessarily abrupt or clearly defined. Many forest habitats, for example, give way gradually at the outer margins to open habitats such as grasslands. In some cases, however, it is very clear where a habitat begins and ends. Caves are habitats that are frequently well delineated by their geology. Life within is defined by factors such as low light levels and the availability of food. Conditions at a cave's entrance are often very different to those further into the cave. Similarly, the deep-sea hydrothermal vent habitats discovered in recent years occur only within very well-defined and highly productive oceanic areas.

**From high to low** Altitude as well as latitude play a part in delineating habitats. The snow-covered peak of Mt. Kilimanjaro contrasts with the semiarid veldt below.

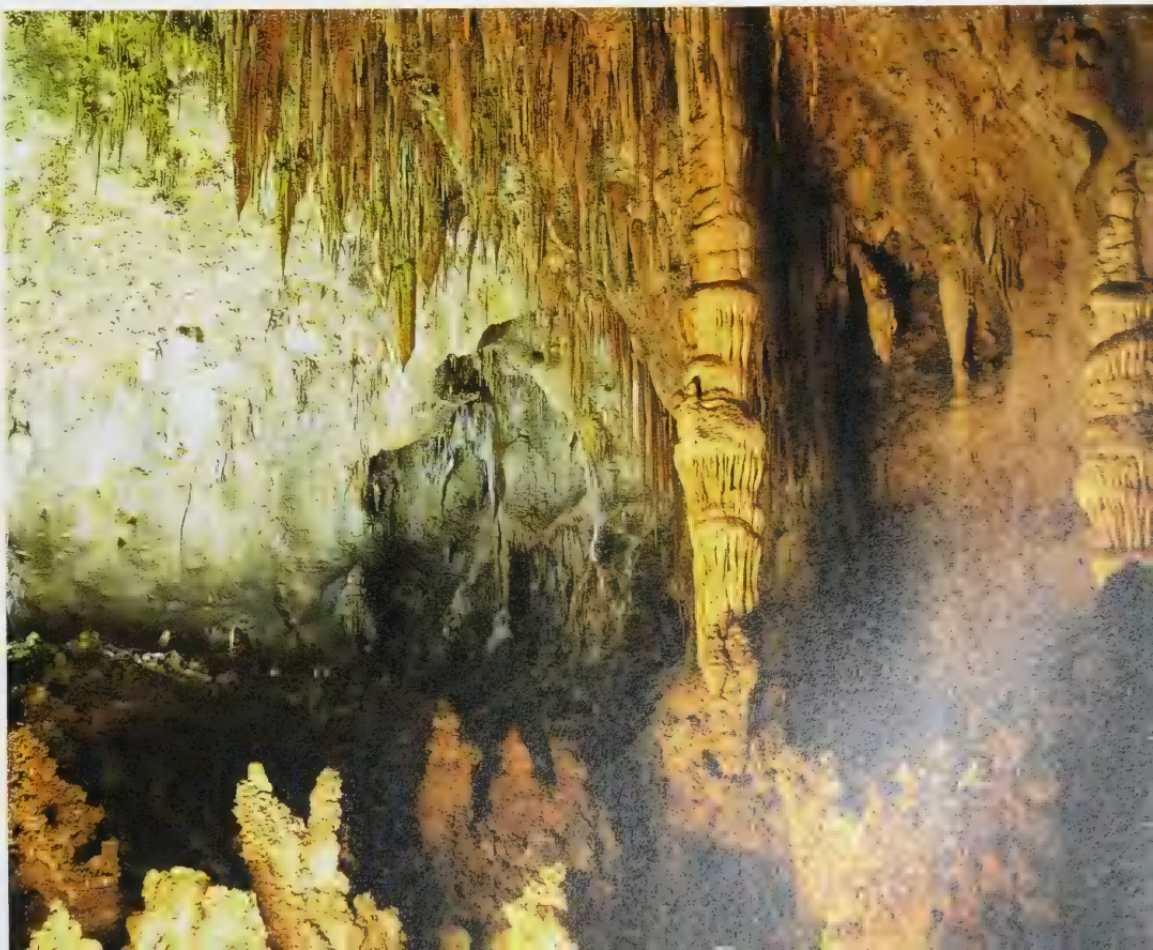
**Carlsbad Caverns National Park** This seemingly inhospitable, vast cave complex in New Mexico is a habitat for bats during the summer breeding season. They hang from the ceilings in their thousands.

## ENVIRONMENT CHANGE

Habitats are not fixed or static, and it is natural that they change over time. Many are shaped by sudden, dramatic geological events such as earthquakes and volcanoes, while some shift more slowly in response to a persistent natural force such as erosion. Changing weather patterns often create seasonal, recurring, and reversible change. In addition, some habitats change in response to the animals and plants that are living and evolving within them.

However, many changes being witnessed within Earth's habitats are not the result of natural forces or events. Rather, it is human activity that now drives the most significant transformations. Most habitats, for example, are shrinking in area. Major exceptions include the ever-expanding desert, semi-desert, and urban habitats. It is also significant that the diversity of life within most habitats is seen to be on the decline.

The more complex and species-rich habitats, such as the rain forests and coral reefs, were once thought to be the most resilient to change. In recent times, however, they have exhibited signs of being among the most fragile.



# RAIN FORESTS

Rain forest is a moist and exceptionally biodiverse habitat dominated by broad-leaved trees with shallow root systems. Annual precipitation exceeds 40 inches (1,000 mm) and falls consistently throughout the year. Tropical rain forest occurs in more than 80 countries (largely those in South and Central America, West Africa and Southeast Asia), stretching around the equator between the tropics of Capricorn and Cancer. It covers just 7 percent of Earth's land surface but supports at least half of all the plant and animal species. Temperate rain forest occurs in cooler climes, particularly along North America's Pacific coast and in pockets of southern Australia, New Zealand, Norway, Japan, and the United Kingdom.

**Egg strategy** The red-eyed tree frog (*Agalychnis callidryas*) lays its eggs on leaves overhanging water. As soon as the tadpoles hatch, they wriggle down into the water.

**Under cover** The ocelot (*Leopardus pardalis*) is dependent on the dense cover afforded by parts of the rain forest for its protection. Its spotted coat also acts as camouflage. Ocelots came under the protection of the International Convention of Trade in Endangered Species in 1975

**The Nouragues Reserve** The canopy of this rain forest in French Guiana, northern South America, is home to numerous bird species such as macaws and toucans. Well hidden from view, in the lower regions of the forest, are jaguars and other big cats

## LAYERED LIFE

Rain-forest life takes place within vertical layers. The highest treetops reach up to 130 feet (40 m), creating an emergent sunlit, windy stratum patrolled by large predatory eagles.

Most tree crowns, however, stop just below this height to form a leafy canopy rich in insect life and so dense it is almost impenetrable to sunlight. The birds and mammals that abound here rarely descend to the forest floor. Communication by sound is common and this stratum rings constantly with a cacophony of howls, whistles, and screeches.

Low-light adapted shrubs and small trees frame an understory in which big cats, such as the jaguar in South America and the clouded leopard in Southeast Asia, hunt.

The forest floor is home to an array of insects as well as rodents and large mammals such as tapirs, elephants, and gorillas.

Exceptionally high moisture levels mean that frogs and other animals normally associated with aquatic environments are found in greater abundance in rain forests than in other terrestrial habitats.

# TROPICAL MONSOONAL FORESTS

Tropical monsoonal forest, known also as tropical deciduous forest, grows in areas of high annual precipitation that falls mostly during a distinct wet, or monsoon, season. This habitat experiences a distinct dry season during which no, or scant, rain falls and most trees and shrubs lose their leaves. Monsoon forest trees do not grow as tall as those in rain forests, and the understory is more developed because it receives higher levels of light. There is a distinct seasonality to life in this habitat because most plants flower and fruit at the onset of the wet season. Monsoon forest is most common in Southeast Asia.

**Formidable lizards** The Komodo dragon (*Varanus komodoensis*) is found on a few tropical islands in central Indonesia. These fierce animals feed primarily on carrion but also prey on large mammals such as deer and water buffalo

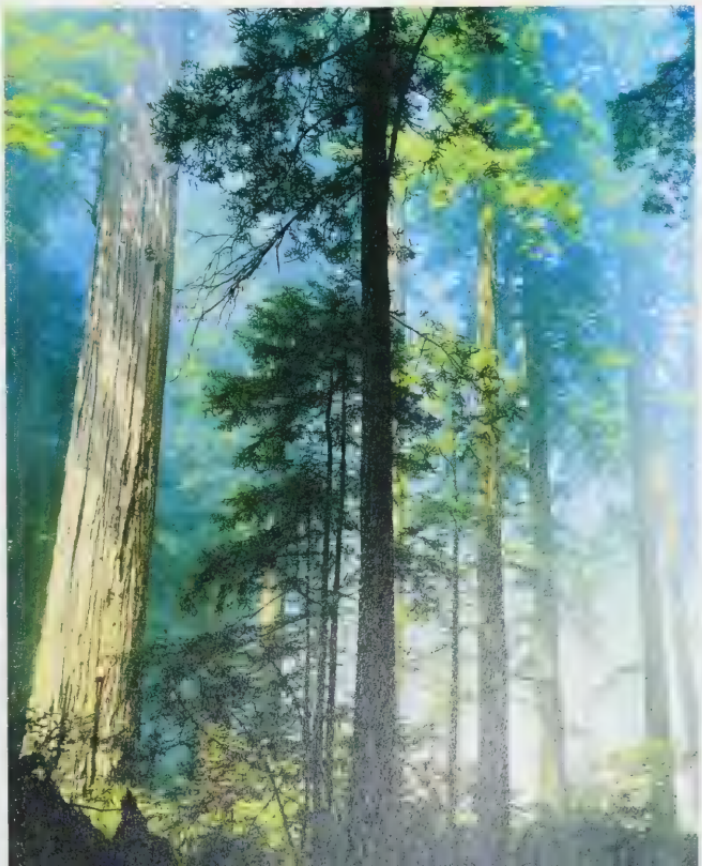
**Enveloped city** Almost hidden in the encroaching tropical forest is the city of Mrauk-U, Myanmar (Burma). Depletion of forests in some areas to service the needs of the human population is causing loss of animal and plant habitat

# CONIFEROUS FORESTS

This habitat is dominated by evergreen coniferous trees such as firs and pines, which have mostly thin, needle-like leaves and produce seeds in cones. They usually occur in areas with long, very cold winters and moist, short summers. Animal life here often avoids harsh winters by hibernation or migration. Huge areas of land in the Northern Hemisphere are covered with coniferous forest, known as taiga or boreal forest, that stretches right around the northern end of the planet, between about 50 and 60 degrees north. Coniferous forest is also a feature of mountainous areas throughout the rest of the world.

**Gypsy moths** A naturalist brought the gypsy moth (*Lymantria dispar*) to the United States from Europe in 1869. Some escaped and the species quickly became a serious pest. The caterpillars consume huge amounts of leaf material in spring Pine and spruce trees are most affected

**Giant among trees** On California's wet north coast, Redwood National Park is a vast area with stands of Earth's tallest tree, the redwood. These slow-growing giants live up to 2,000 years, forming a complex ecosystem in which hundreds of different plants and animals live. Logging poses a continued threat to old-growth forests



# TEMPERATE FORESTS

Temperate forests occur around the world at latitudes between 25 and 50 degrees and are usually dominated by broad-leaved trees. In areas with cold winters beset by frost, as in eastern North America, eastern Asia, and Western Europe, these forests are usually deciduous. The four seasons are well defined, with fall marked by a spectacular color change in leaves before they drop in their entirety. Animals in these forests typically cope with the harsh winters by hibernating or migrating. In temperate forests in South America, southern China, New Zealand, eastern Australia, Japan, South America, and Korea, where the winters are much milder and most often frost-free, the dominant trees are evergreen.

**Grand Teton National Park** In fall, this vast area turns golden. The Snake River meanders through the park. Bald eagles and ospreys are common along the shores. Beavers, weasels, and coyotes frequent the marshes, meadows, and woods.

**Lookout duty** The raccoon (*Procyon lotor*) is a solitary mammal that spends its days sleeping in hollow trees, or a burrow in winter. The forest floor is rich in organic matter that feeds the animal population.

**Marsupial downunder** The Leadbeater's possum (*Gymnobelideus leadbeateri*) feeds on plant exudates and insects. Extensive logging in areas of Australia's old-growth forest that is already have put its survival at risk. It is now classified as endangered.

## SEASONAL LIFE

A distinct seasonality marks the life of animals that dwell in temperate deciduous forests. As spring nears, the weather warms and food begins to become plentiful. Hibernating residents such as the hedgehogs and bears awaken. Great numbers of species return from over-wintering in warmer climes. Many migratory birds, in particular, arrive to feast on the booming insect populations so typical of these forests in spring. Also, courtship and reproduction proceed at a frenzied pace so that offspring can be born and have a solid start to life while conditions are at their most favorable.

Seasonal lines aren't always so well defined in evergreen temperate forests. Life doesn't batten down the hatches to survive through the cold months in the same extreme way, and the peak period of growth and reproduction tends to start earlier, in the late winter. These forests also tend to have more well-developed understorys of shrubs and the smaller trees so that ground-dwelling species are more plentiful than they are in their deciduous counterparts.

**An ancient oakwood forest, England** Oaks are hardy and long-lived shade trees. They bear catkins (male flowers) and spikes (female flowers) on the same tree.

# MOORLANDS AND HEATHS

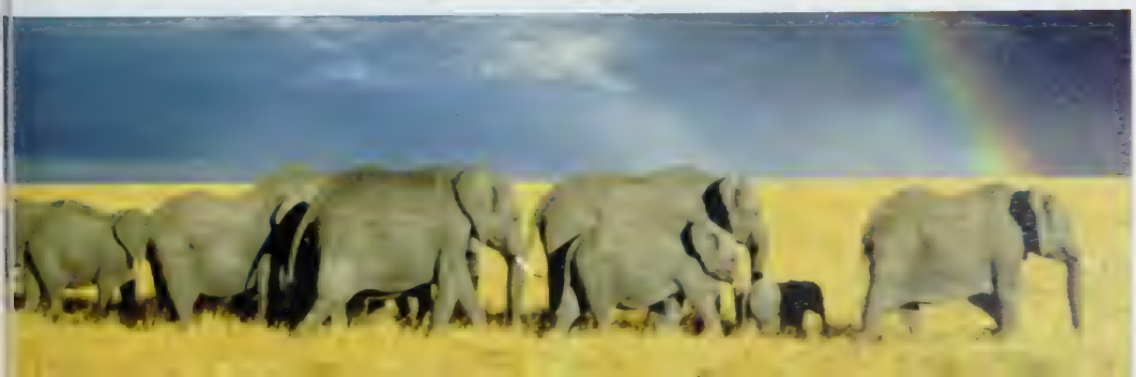
This harsh habitat features dwarfed bushes and grasses and little other vegetative cover, so most animal life tends to live close to or under the ground. Although often associated with the United Kingdom, moorlands occur worldwide in exposed or high open areas, along coastlines and on mountains. The Ethiopian highlands, for example, are dominated over large sections by moorlands inhabited by the critically endangered Ethiopian wolf (*Canis simensis*). In Europe, the moorlands are often associated with heath in a habitat that was originally created, up to 5,000 years ago, when woodland was cleared by early farmers. This now supports endangered species such as the natterjack toad (*Bufo calamita*).

**Torres del Paine National Park** This park in Patagonia, Chile (far right), comprises steppes, heath, forest, and desert—and is home to numerous species of mammals including the guanaco (*Lama guanicoe*). These, the larger of the two wild camelid species, thrive in the rough terrain.

**Drawn to honey** Honeyeaters are largely restricted to the Australasian region. These birds have a uniquely structured tongue. It has a deep cleft and is fringed at the tip so that it forms four parallel brushes. This is an adaptation to nectar feeding. Here, a yellow-faced honeyeater (*Lichenostomus chrysops*) is feeding on banksia nectar.

# OPEN HABITATS

Low annual rainfall of 20–30 inches (500–750 mm) limits tree growth in these places, which often represent transition zones between forests and deserts. Sprawling flatlands dominated by grasses offer few hiding places for large animals. Nevertheless, this habitat type is often dominated by big herbivores. Grazing together exploits a safety-in-numbers strategy that is intended to confuse and overwhelm potential predators. Huge herds of bison and pronghorns once roamed North America's prairies. Africa's savanna is still renowned for massive, albeit declining, mobs of zebras, antelope, and other large mammals that are hunted by big cats and wild dogs. Other open habitats include the Ukrainian steppes, the South American pampas, and southern Africa's veldt.

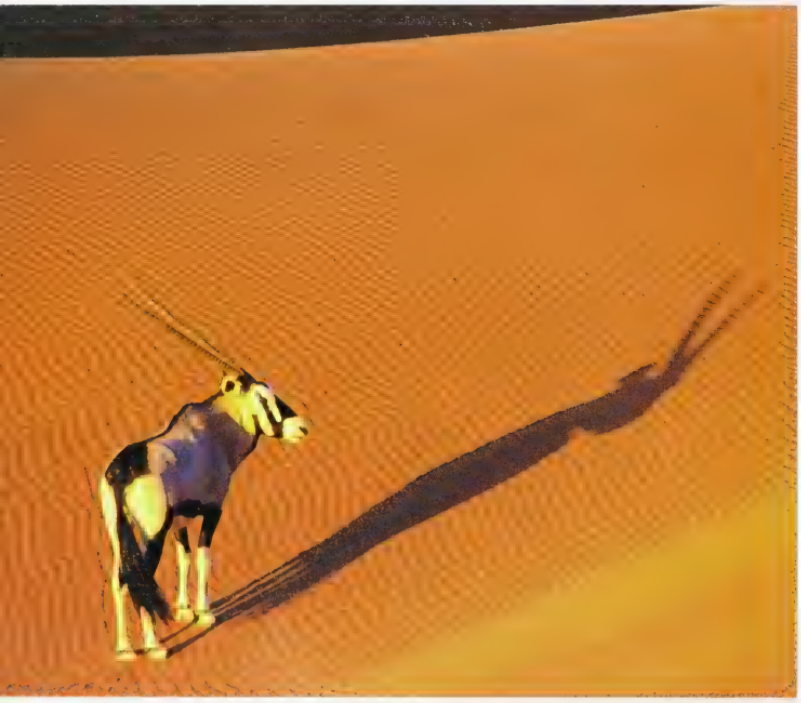


**High rise** [illegible]

**Serengeti** [illegible]

# DESERTS AND SEMIDESERTS

These habitats, which cover about one-third of the planet's land surface, are characterized by a lack of moisture. This is caused by high evaporation or low precipitation rates, or a combination of both. The deserts average less than 10 inches (250 mm) of rain per year, while semiarid habitats receive 10–20 inches (250–500 mm) annually. Precipitation is typically sporadic and unpredictable. Most of the world's driest areas lie between 15 and 40 degrees north and south of the equator. Searing daytime temperatures are common but do not define these habitats. They frequently experience freezing overnight temperatures. Much of the Antarctic, which is bitterly cold year-round, fits the definition of desert.



**Desert strategies** The gemsbok (*Oryx gazella*) [illegible] When it pants, the rapid [illegible] of air passes over a [illegible] of blood vessels, cooling the blood [illegible] to the brain. The gemsbok feeds mostly at night when the temperature is much cooler. [illegible] back and standing [illegible] that quiet grip [illegible]

**A sideways move** In order to move over surfaces such as loose sand and soft mud, snakes adopt a locomotion method known as sidewinding. The snake uses a point of contact with the ground as purchase, then lifts its trunk clear of the ground to secure another point of contact. Shown here is a Peringuey's desert adder (*Bitis peringueyi*) sidewinding its way across a dune in the Namib Desert in Africa

**Fog catcher** Fog rolling in from the coast is the only regular moisture in the Namib Desert. To utilize this resource, the darkling beetle (*Onymacris baccus*) points its rear into the wind and patiently waits while fog condenses on its back and water droplets trickle along dorsal grooves to its mouth

## HIDDEN LIFE

These habitats invariably support more life-forms than most people appreciate. Extreme temperatures and dryness are the major concerns for desert-dwelling animals, and most manage to cope by using a combination of physiological and behavioral adaptations.

The smaller animals are typically nocturnal, hunting and foraging under cover of darkness to avoid the daytime higher temperatures and evaporation rates. These animals include a range of arthropods such as spiders, centipedes, and scorpions as well as gerbils, ground squirrels, kangaroo rats, and other mammals. Underground burrows are the most common source of shelter during the day, due not only to the lack of vegetative cover but also to the milder conditions that usually prevail below ground.

Heat absorption in large animals, including camels, goats, donkeys, emus, and ostriches, is limited by thick coats of fur or feathers. These limit heat loss as well, however, and so these animals also have sparsely covered regions of the body for the purpose of emitting excess body heat.

**Ostriches on a salt plain** [illegible]

# MOUNTAINS AND HIGHLANDS

Mountains are like terrestrial islands. The process of evolution often occurs in isolation, so that the animals on one mountain can be unique from those of other mountains—even those located nearby. Life in the mountains, however, always displays a layered pattern to its structure, mainly because the climatic conditions alter with altitude. Air gets colder, for example, with increasing elevation, so that even tropical mountains such as Mt. Kenya and Mt. Kilimanjaro, both in Africa, can be permanently capped with snow. Agility is a feature of large mountain animals such as the chamois in Europe and the snow leopard in Asia. The smaller animals often shelter from environmental extremes in burrows and hibernate in winter.

**Scavenger of the sky** The king vulture (*Sarcoramphus papa*) rises on thermals, and soars great distances. It is unable to smell carrion and often works with turkey vultures, relying on them to detect a carcass. Once one is discovered, the king vulture descends, rips open the carcass, eats its fill, and then lets other birds feed

**Fog in the Pyrenees** The thick fogs, high peaks, and winter snows of the Pyrenees create a daunting barrier between France and Spain. The areas of high pasture in the Pyrenees were once a habitat for raising livestock. Now, the economy of European high mountains is increasingly focused on tourism and recreation

# TUNDRA

True tundra is one of the harshest and least biologically diverse habitats: a vast, treeless, Northern Hemisphere world north of 55 degrees latitude covering one-fifth of Earth's land surface. Very little snow or rain falls and nutrients are scarce. During the long, bitterly cold winters, unbroken darkness endures for months and the ground remains frozen to a depth of a least 10 inches (25 cm). Summers are exceptionally short. The Sun shines 24 hours a day, the upper permafrost melts, and shallow, ephemeral lakes form in the wet ground. Migratory insects, birds, and mammals move in to take advantage of this very limited growing season.

**Musk oxen, Alaska** In the bitter cold, fur and feathers are important survival tools. The musk ox (*Ovibus moschatus*) has a hair 24–36 inches (60–90 cm) long, which is the longest of any animal. Plant matter is [illegible] into soft patches of snow to feed and are among the most heavily feathered of [illegible]

**Arctic tundra in fall** [illegible]

# POLAR REGIONS

Antarctica is the coldest, windiest, driest continent and the Arctic is almost as inhospitable. Despite this, a surprising level of animal life is able to survive at the poles. The Arctic Ocean, for example, supports some of the world's most productive fisheries, while in Antarctica, Wilson's storm-petrel (*Oceanites oceanicus*) is a bird that breeds in its millions. Extreme cold is the main driver of animal adaptations. Thick layers of fat and fur or feathers help prevent heat loss in mammals and birds. Often the animals migrate seasonally to avoid the harshest conditions. Many fishes and invertebrates are protected by a natural "antifreeze" in their body fluids.

**A parade of penguins** From a young age, the thickset Adélie penguin (*Pygoscelis adeliae*) grows dense, short, fur-like feathers that provide protection from icy conditions in the Antarctic

**Cold comfort** Polar bears (*Ursus maritimus*) have a mechanism limiting heat loss. Warm blood from the heart transfers heat to cool blood returning from the skin.

**Beneath the ice** Seafloor-dwelling species such as sea anemones and sponges are able to survive and flourish in the relatively tranquil waters where the spread of polar ice does not extend.

# LAKES AND PONDS

Some 5 million lakes and many more ponds are scattered across the continents. The older they are, the more biodiverse they tend to be, and the more endemic species they contain. Most pond and lake fauna falls into three distinct categories. Zooplankton live mainly in the surface waters and are tiny animals such as crustaceans and rotifers. Nekton includes fishes and some large invertebrates that consume zooplankton and live throughout the water column. They also feed on benthic animals, mostly invertebrate bottom-dwellers such as insects, crustaceans, and mollusks. Most ponds and lakes also have animals living on and in surrounding vegetation and in bank sediments.

**The Pantanal** This area is a haven for one of South America's greatest concentrations of wildlife—home to more than 600 bird species. In the wet season, it becomes the world's largest freshwater wetland.

**At rest before migration** The snow goose (*Anser caerulescens*) breeds in the Arctic regions of North America on the tundra and winters on the Pacific coast in salt marshes and marshy coastal bays

# SEAS AND OCEANS

Covering almost three-quarters of Earth's surface and with an average depth of 10,500 feet (3,000 m), these vast marine environments comprise more area than any other habitat. Most animals are pelagic (living within the water column) or benthic (bottom-dwellers). Pelagic fauna ranges from the tiny planktonic creatures drifting at the mercy of the currents to strong swimmers such as marine mammals, fishes, and squid. Sunlight has a direct impact on life in the surface layers of open water and in shallow benthic communities. And its absence, along with increasing pressure, has been a key force behind many adaptations of animals living in the depths of the oceans.

**Breaching dolphins** The spinner dolphin (*Stenella longirostris*) is famous for its fantastic spinning leaps. Its main threat has come from tuna fisheries, which have caused hundreds of thousands of deaths.

**Kelp forest** A dependence upon sunlight for photosynthesis restricts kelp forests to clear, shallow water. Various invertebrates attach to drift kelp, including nudibranchs and barnacles.

# MANGROVE SWAMPS

Mangrove swamps stabilize shorelines in wave-protected river deltas, estuaries, and coasts in the tropics and subtropics. Almost three-fourths of tropical coastlines are narrowly fringed with this valuable habitat. It is dominated by salt-tolerant, shallow-rooted trees and shrubs. The tangled, extensive roots of these plants stabilize sediment, capture vegetation, and create an environment in which decomposing organisms ranging from bacteria to worms can flourish. They also provide substrate and shelter for a wide range of larger invertebrate fauna from mollusks to crustaceans. Although rarely entered by large vertebrates, mangrove swamps play a critical role as nurseries for a wide range of fishes at the larval and juvenile stages.

**Barnacle feast** Aerial roots that carry air down to the bottom roots of mangrove trees form vertical microhabitats with distinctive zoned communities of animals. The position of this mangrove crab (*Scylla serrata*) on the root is determined by the animal's tolerance of tidal exposure.

**Coastal mangroves** Cordgrasses and mangrove plants have root systems that exclude most of the salt in the water they take in. Any that does make its way into the plant sap is excreted through pores on the surface of the grass blade or mangrove leaf.

# CORAL REEFS

The foundations of coral reefs are formed largely by the hard external skeletons of small invertebrate animals called polyps, close relatives of sea anemones and jellyfishes. Not all coral polyps are capable of forming reefs. Those that are capable are classified as hard corals and live in interconnected colonies in which individuals extrude and sit within hard, protective, cup-shaped deposits of calcium carbonate. As these animals die, they leave behind their skeletons and successive generations of polyps build on top of them. Other invertebrate animals that produce calcium carbonate, including sponges and mollusks, as well as certain algae, also contribute to coral-reef formation.

Deep-water coral reefs

Warm ocean

Warm-water coral reefs

**Life on the reef** Coral reefs support an abundant, colorful, and diverse group of animals that live on, burrow into, and even eat, the hard coral. Inhabitants face strong competition for food, space, and mates, and the constant threat of predators

## RESTRICTIVE NEEDS

Limestone coral polyp skeletons provide a substrate upon which other sedentary invertebrates and algae settle and grow, and within which a huge diversity of animal life lives, feeds, and shelters.

Most of the world's coral reefs are located between the tropics of Capricorn and Cancer. They are best developed in clear waters with temperatures of 70–85°F (21–29°C) and at depths of less than 33 feet (10 m). This is due for the most part to the temperature and light requirements of unicellular algae, known as zooxanthellae, which live in a symbiotic relationship within coral polyp tissue. The hard, reef-building corals cannot live without zooxanthellae. They produce the essential nutrients for the polyps, which in turn provide food and shelter for the algae.

The most common coral reefs are the fringing reefs that run parallel to the coast and are separated from shore waters by shallow lagoons. The largest are barrier reefs which, similarly, run parallel to coastlines but also run beside wider and deeper lagoons.

**Fragile habitat** Every year, the world's reefs are damaged by oil pollution, sewage, sedimentation, over-fishing, and the effects of global warming. Cold-water corals are also under threat from trawling.

**Great Barrier Reef, Australia** This reef is the biggest of all coral structures, and the largest biological entity on Earth. Warm-water coral reefs rival tropical rain forests in the range of flora and fauna they support.

# COASTAL AREAS

Beaches, oceanic cliffs, sand dunes, intertidal rock pools, and shallow coastal waters are all included in this habitat. Life in these coastal areas can be exposed to fierce winds, salt-laced sea spray, crashing waves, and tidal influences. Invertebrates are the dominant animals, from predatory polychaetes that burrow and hunt on moist beach sands to well-camouflaged, hard-shelled gastropod mollusks clinging with amazing tenacity to rocks constantly battered by waves. Marine birds breed on cliff faces and patrol beaches and rocky shorelines for food. And in some protected coastal areas, marine mammals such as seals haul themselves up to mate and raise their young. Marine turtles, too, find their nesting sites on certain select beaches.

**Dugong grazing** Dugongs (*Dugong dugon*) are found in the coastal waters of the Pacific and Indian oceans. Their few defenses, coupled with low reproduction rates, have resulted in their classification as vulnerable

**Rocky shores** The Twelve Apostles in Victoria, Australia, is a marine national park and sanctuary. Underwater arches, canyons, caves, and walls attract schools of reef fishes and breeding colonies of birds

# RIVERS AND STREAMS

Animal life in these habitats is strongly influenced by water-quality characteristics such as dissolved nutrient levels, oxygen content, and turbidity as well as the pace of water flow. The more consistent these are, in both space and time, the more diverse life tends to be. Some rivers and streams experience major seasonal fluctuations, their waters swelling and racing with summer rains or spring thaws, and animals often have life-cycles that accommodate such extremes. Life also tends to be best adapted to either benthic or open-water environments, as it does in other aquatic habitats. River and stream banks and vegetation provide additional niches.

**Leaping food** Grizzly bears (*Ur[illegible] horribilis*) emerge hungry from their winter hibernation. They forag[illegible] beside streams until the s[illegible] each summer. Strea[illegible] salmon, the fishe[illegible] to head. Bear hie[illegible] ensures that the big[illegible] best fishing [illegible]

**Hippopotamuses in a** [illegible]

# WETLANDS

Wetlands are often vital to the health of other habitats because they soak up and slow down rising floodwaters and filter out and capture the excess nutrients, sediments, and pollutants before they can reach bodies of open water. It is for the latter reason that they are sometimes described as Earth's kidneys. Water-soaked and characterized by sodden soil, wetlands encompass all the fresh and brackish water environments that lie between dry land and open water. Different types include swamps, marshes, fens, floodplains, deltas, and bogs. Many are permanent while some form seasonally. They are found worldwide along rivers, streams, and lakes and in flat areas inundated by melting snow or rising water tables.

## CRITICAL REASSESSMENT

Up until the latter decades of the past century, wetlands were widely held to be unproductive wastelands worthy of little other than in-filling. As a result, many have been destroyed or damaged. These days, about 6 percent of the world's land surface is thought to be still covered by these habitats.

It is now understood and widely appreciated that as well as helping to protect and purify other habitats, wetlands support an extensive variety of plant and animal species, most of which have both terrestrial and aquatic adaptations. Permanent wetland residents include fishes; amphibians such as frogs and toads; turtles, crocodiles, snakes, and lizards; and, a range of invertebrates, including insects and crustaceans.

But wetlands are also often crucial, transient places of residence for migrating animals, particularly birds. Some exploit wetlands as stopovers for feeding and resting while en route to other locations. But many, such as herons, egrets, pelicans, and other waterbirds, also use them as breeding grounds.

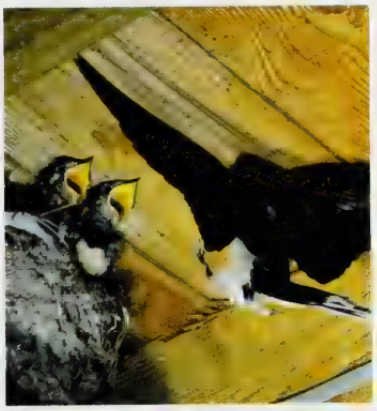
**Alligator resting** The American alligator (*Alligator mississippiensis*) resides in the swamps of the southeastern United States When hunting, it uses its heavy head to smash through densely vegetated areas, and then grabs its victim in its blunt, broad jaws

**Horses in the Camargue** A breed of wild, small, white horses is found only on the Camargue—a wetland and salt marsh area in southeastern France. The hardy animals are able to weather the bleak, cold winters and very hot summers of the region

**Preening spoonbills** Roseate spoonbills (*Platalea ajaja*) inhabit the coastal swamps of the Americas. To feed, a bird sweeps its elongated, partly open bill from side to side in the water. When prey is found, the bill snaps shut over the food in an instant

# URBAN AREAS

In urban habitats, humans and their activities are dominating forces. Upper levels of food chains, for example, are controlled by people and their domesticated animals, such as dogs and cats. Such factors combine to ensure that the animal life of urban areas is comprised of a small number of species with many individuals. Animals with opportunistic or wide-ranging diets and shelter requirements abound, including sparrows, pigeons, rats, cockroaches, and other insects. Those animals with boom-or-bust population cycles tend to do particularly well. However, species with naturally low reproductive rates rarely survive. Nor do those with narrow habitat requirements or those sensitive to air and water pollution, such as many frogs.



**Swallow feeds its young** Swallow nests are made of layers of grasses and small mud or cow-dung pellets. To protect them from disintegrating in the rain, swallows choose a site such as rafters in barns, or under bridges.

**High-rise living** Largely a cliff-nesting species, the Peregrine falcon (*Falco peregrinus*) has adapted to nesting on the ledges of large buildings in North American and European cities. This fierce, fast predator can kill in mid air.

# PARASITIC LIFESTYLES

Some animals, mostly small invertebrates, exist for all or much of their lives inside other organisms. To survive, these parasites need to be adapted to the internal chemical and physical environments of their plant or animal hosts. They also need to resist or respond to the defences targeted at them by the immune systems of the organisms in which they live. Animals that lead parasitic lifestyles require a way of passing between hosts. For some this means surviving the rigors of the external environment with encysted or resilient dormant stages. Others use the bodies of other organisms as intermediate hosts to avoid external habitats.

**Overwhelmed** Parasitic wasp insects (left) often lay their eggs in paralyzed but [illegible] living caterpillars so that the young have a source of fresh food. Sometimes, more than one parasite lays in a single caterpi[illegible]

**Unwelcome guest** Nema[illegible] worms (left) of the [illegible] family are a common [illegible] Lodged in the [illegible] their [illegible]

**Grasshopper residents** [illegible] and feed [illegible]

# ANIMALS IN DANGER

Biodiversity is the total of all animals, plants, and microorganisms living on Earth, and the genetic information that they carry. The term encompasses the way in which species interact with one another as well as with the ecosystems in which they live. Research has shown that preserving biodiversity is essential to habitat health and stability, which, in turn, can have profound quality-of-life and economic implications for human populations. Another argument for maintaining as many of Earth's species as possible is that their genes often provide a source of new substances for industrial or medical applications. Further, because biodiversity has been involved in the development of all human cultures, there are spiritual arguments in support of species conservation.

**Amazon clearance** The rain forest is not inexhaustible, yet logging continues (left) Though the lushness of the forest suggests that it is growing on rich soil, the reality is that regular heavy rain leaches most of the nutrients from it: nutrients within the ecosystem are fixed in the living wildlife. When organisms die, they break down and the minerals are taken up by the forest. If large areas are cleared, the soil is depleted in a few years and the trees cannot regenerate

**Modern medicine** In the search for new pharmaceuticals, the skin secretions of toads and frogs such as Australia's green and golden bell frog (*Litoria aurea*) are receiving attention. Some frog skins are known to have antibiotic properties, and research suggests that these host defense compounds have great potential in the world of medicine. Hence, the need to protect frogs such as the vulnerable green and golden bell frog gains added impetus

## MAJOR THREATS

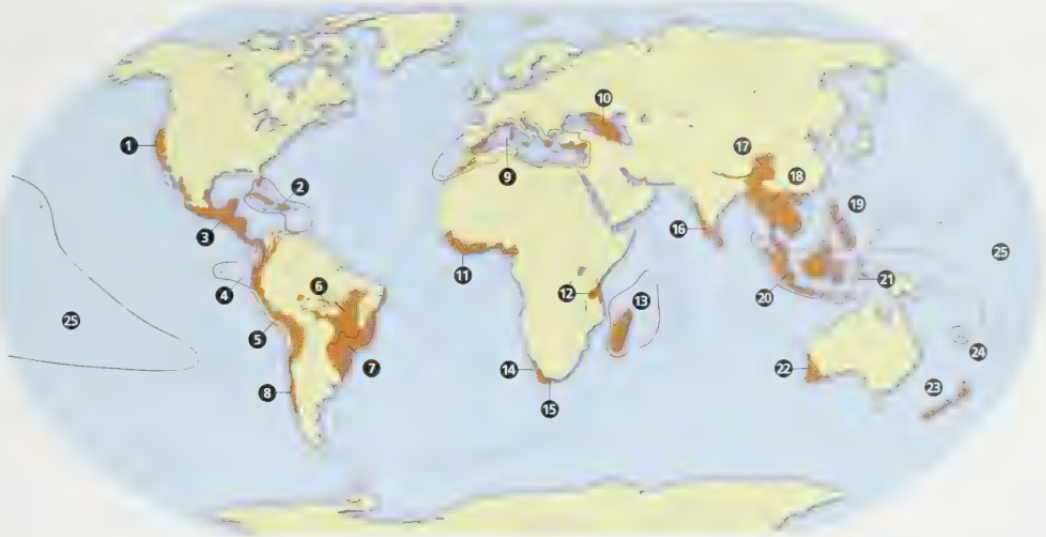
As a result of the expanding human population, Earth is experiencing high levels of biodiversity loss with extinction rates estimated to be at least a thousand times higher than they would have been before our own species first evolved. Climate change threatens animals and plants, as does the pollution created by the sheer magnitude of people and the technologies employed in daily life. Further hazards are habitat loss and degradation due to inappropriate land use and land clearing, and overexploitation through poaching and illegally sanctioned hunting and commercial harvesting. Competition from species of flora and fauna that have been introduced accidentally or intentionally has also left an indelible mark.

According to a 2004 report by an international team of experts published in the scientific journal *Nature*, climate change alone shows the potential to cause staggering ecological damage in the near future. The authors of the report, which is entitled "Extinction Risk from Climate Change," warn that among the effects of global warming could be the extinction of well over one million species of mammals, birds, reptiles, frogs, invertebrates, and plants by 2050.

**The Tsingy de Bemaraha Strict Nature Reserve, Madagascar** The Indian Ocean island [illegible] of African land area, but has more genera than [illegible] African plants, all of the [illegible] The Tsingy de Bemaraha Strict [illegible] and other [illegible] and birds, but many [illegible] agriculture, [illegible] and building [illegible] causing [illegible]

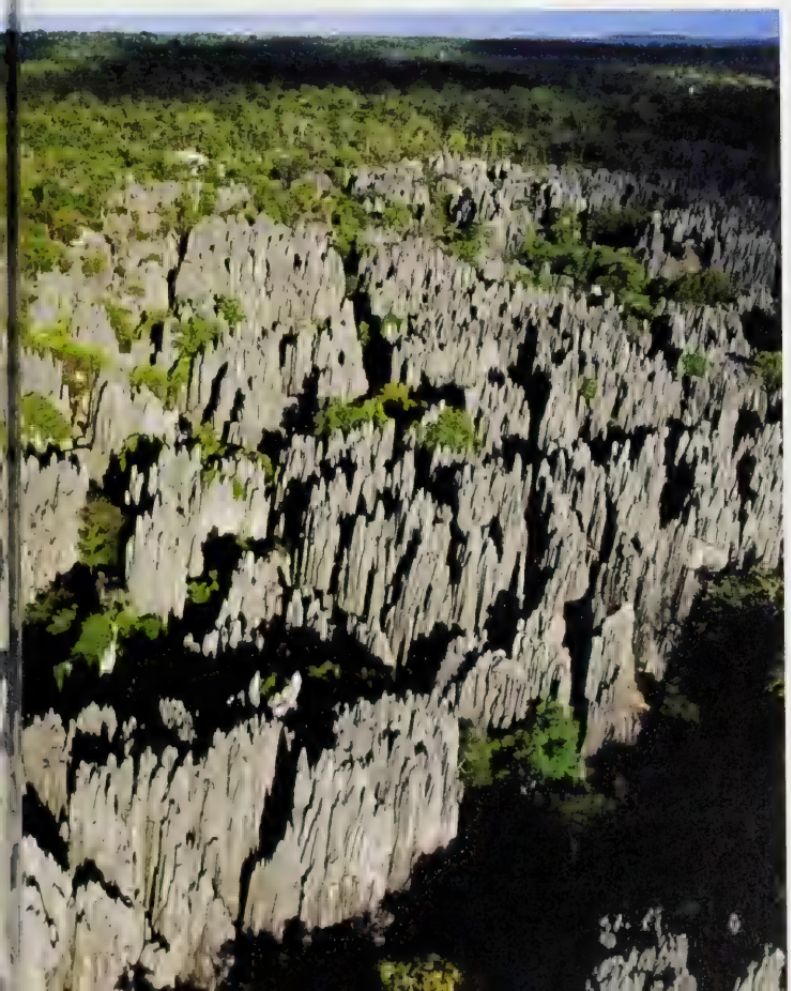
**Biodiversity hotspots**

1 California Floristic Province
2 Caribbean
3 Mesoamerica
4 Chocó-Darién–Western Ecuador
5 Tropical Andes
6 Brazilian Cerrado
7 Atlantic Forest
8 Central Chile
9 Mediterranean Basin
10 Caucasus
11 Guinean Forest of West Africa
12 Eastern Arc Mountains and Coastal Forests
13 Madagascar and Indian Ocean Islands
14 Succulent Karoo
15 Cape Floristic Region
16 Western Ghats and Sri Lanka
17 Mountains of Southwest China
18 Indo-Burma
19 Philippines
20 Sundaland
21 Wallacea
22 Southwest Australia
23 New Zealand
24 New Caledonia
25 Polynesia and Micronesia



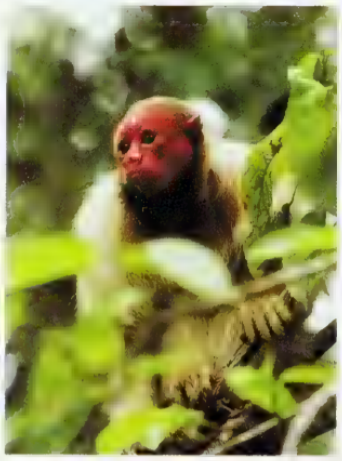
**Targeted strategies for survival** The hotspot concept identified the richest and most threatened areas of biodiversity, where conservation resources could be used to maximum benefit. The biological basis for hotspot designation is plant diversity. To qualify, a region must support 1,500 endemic plant species, 0.5 percent of the global total. Existing primary vegetation is the basis for assessing human impact. A region must have lost more than 70 percent of its original habitat. The 25 hotspots shown on the map have all been badly affected by human activities. Combined, they contain 44 percent of all plant species and 35 percent of all terrestrial vertebrates, in only 1.4 percent of Earth's land area.

**Long gone** The loss of the dodo (*Raphus cucullatus*) is a classic example of human disregard for wildlife. Discovered in 1507 on islands in the Indian Ocean, the dodo weighed about 50 pounds (23 kg) and had useless stubs for wings. With no means of escape from seafarers who killed it for sport and for food, the bird was extinct by 1680.



**Stop the traffic** Trafficking in wild animals is a multimillion-dollar business. It feeds the demand for exotic creatures as pets, for food, and as material for decorative objects. The majority dies in transit. Below, river terrapins (*Batagur baska*) are examined after authorities intercepted the traffic of 1,500 live turtles bound for China in 2002

**Agile rock climber** Chamois (*Rupicapra rupicapra*) are fleet-footed inhabitants of the Pyrenees and other mountain regions in Europe. Although not threatened as a species, the numbers of some subspecies are declining due to excessive hunting and competition from livestock. In some areas, chamois species are being introduced or reintroduced with good results



**Do not disturb** Overfishing of Tasmania's giant freshwater lobster (*Astacopsis gouldi*) has reduced breeding-age animals to a dangerous low. Males and females of this species take 9 and 14 years respectively to reach sexual maturity. Here (above right), a specimen is being tagged and measured before being returned to the wild

**Red for danger** The bald uakari (*Cacajao calvus*) lives in Brazil and Peru in swampy, flooded forests. It and its subspecies are classified as near threatened by the IUCN due to mining and logging. These activities have [illegible] hunters who [illegible] uakaris for food or sell them as pets

## THE SIXTH EXTINCTION

Scientists believe that, under natural extinction rates, the planet should be losing an average of one species every 4 years. However, estimates put the loss at about 17,000 species each year, the vast majority vanishing before their existence has even been scientifically documented. For many esteemed ecological commentators, this loss constitutes the sixth mass extinction to have taken place in the history of life on Earth. The last one occurred 65 million years ago when more than three-fourths of all species that were alive at the time, including the vast array of dinosaurs, disappeared for ever.

Scientists agree that all other mass extinctions can be linked to some form of natural phenomenon. The blame for the current crisis, however, rests firmly, they contend, on global human activities. It is possible—some scientists believe inevitable—that the same factors driving the current mass extinction could ultimately bring our own species to the brink. Such a bleak prognosis is alleviated by the news that many experts believe we have the means, and just enough time, to significantly slow, and possibly even halt, the current extinction drama that is unfolding. What is even more vital, though, is the will to do it.

**Creature of myth and mystery** Snow leopards (*Uncia uncia*) are elusive inhabitants of high mountain areas of central Asia. Our knowledge of these animals has increased as a result of a program of radio collaring and tracking. Also, farmers are being taught ways to protect livestock without resorting to killing the endangered snow leopard

**On the brink** Australia's Lord Howe Island phasmid (*Dryococelus australis*), thought to have become extinct in the early 1920s, was rediscovered in 2001. Only three specimens of this large, flightless insect (above) were found on the island, but it is hoped that a species recovery program will result in its reintroduction to its former range

## LOSING ANIMALS

The World Conservation Union estimates that one in four species of mammal and one in eight species of bird are now at risk of extinction, as are 25 percent of reptiles, 20 percent of amphibians, and 30 percent of fishes. Countries with the highest number of known threatened bird and mammal species include China, Peru, Brazil, and India. Percentages of known threatened species are smaller for insects and other groups of invertebrates, but that is probably because they contain many more species that remain undescribed.

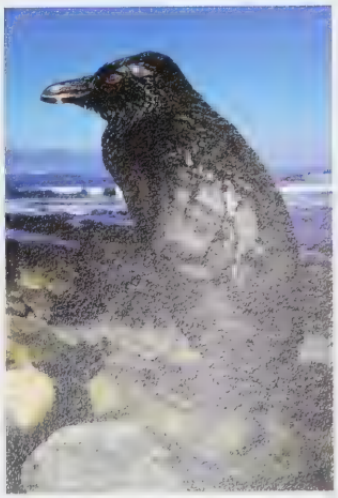
Amphibians are known to be particularly sensitive to environmental degradation. Hence, recent declines in their numbers are widely regarded as a significant sign that the planet's capabilities to maintain current levels of biodiversity are being dismantled.

Among the many rescue attempts now being staged around the world are the last-ditch efforts to save the human race's closest relatives—all four species of great apes—from extinction. The United Nations has predicted that gorillas, orangutans, chimpanzees, and bonobos (pygmy chimpanzees) have just a few decades left before they become extinct in the wild.

**Food for thought** The range of the giant panda (*Ailuropoda melanoleuca*) is steadily shrinking as land clearance affects its habitat. The bamboo on which it feeds is subject to large-scale, periodic die-back. In the past, pandas could migrate to other areas to feed, but habitat fragmentation is making this difficult. Stringent punishment imposed by Chinese authorities has seen a substantial decline in poaching

**Long-distance traveler** The wandering albatross (*Diomedea exulans*) (left) has a vast ocean range and is known to be able to cover up to 9,000 miles (15,000 km) in a single trip. Classified as vulnerable, the albatross is at risk from long-line tuna fisheries, as well as predators such as cats and dogs

**Deadly oil** Classified as vulnerable, the jackass penguin (*Spheniscus demersus*) is a flightless bird endemic to an area off the coast of southern Africa. Oil resulting from illegal discharges from tankers, harvesting of penguin eggs for human consumption, and a reduction in food supply because of commercial fishing are all taking their toll on these birds. On the positive side, the South African National Foundation for the Conservation of Coastal Birds has a high rate of success in saving oiled seabirds.



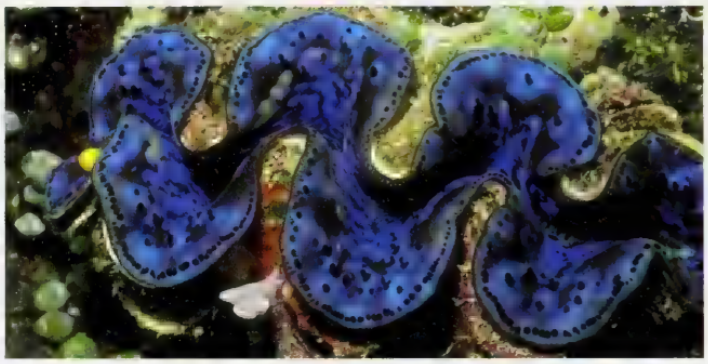
## OCEANS ON THE BRINK

Pollution and overfishing have been of concern in marine environments for a long time. Land clearing, too, is having a deleterious impact because it leads to sediment run-off which interferes directly with life in coastal areas and, ultimately, elsewhere in deeper-water environments. Now, global warming is also seen as a major threat to marine biodiversity.

Inundation in low-lying mainland coastal areas is likely to affect many species dependent upon intertidal environments. Island shores will suffer similar fates and there is a likelihood that some islands will disappear completely beneath the waves, along with their often unique flora and fauna.

Of particular concern are recent scientific predictions that the largest coral system in the world, the Great Barrier Reef in Australia, is likely to lose as much as 95 percent of its coral by 2050 as a result of rising sea levels and ocean temperatures. It is possible that the system could collapse completely by 2100.

Scientists have also discovered that phytoplankton, upon which virtually all marine food webs ultimately depend, are declining at alarming rates, a trend observed most markedly in the waters of the North Pacific.



**The threat of poaching** The giant clam (*Tridacna gigas*) lives only in the tropical waters of the Indo-Pacific. These clams are endangered because their flesh (above) is heavily exploited for human consumption and their shells (right) sold to tourists

**Global warming** Current data indicates that the average global rate of sea level rise is 8 inches (20 cm) per century. This may not seem very much, but for low-lying islands and coral atolls in the South Pacific, this rise will prove disastrous. Many will be submerged by the end of the century

**Shark sale** The fins of many species of sharks (below right) are among the world's most sought-after fishery products. Shark fin soup has been a delicacy for centuries among the Chinese. Excessive harvesting of sharks is putting many species at risk

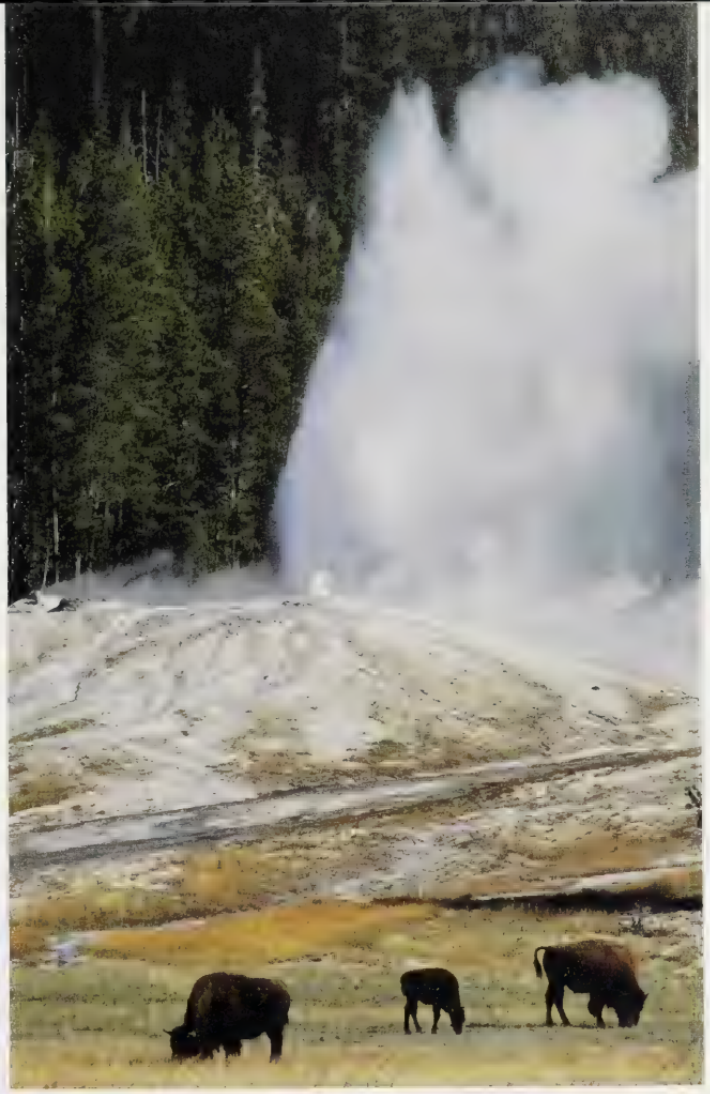
**Fruits of the sea** Huge factory trawlers (left) have helped drive many popular fish species to commercial and even biological extinction. Aquaculture ventures, such as this salmon farm (below), are being touted as promising future sources of protein. But aquaculture can have deleterious impacts on biodiversity where farms are located

## FINDING ANSWERS

Delegates to the 2002 World Summit on Sustainable Development held in Johannesburg, South Africa, agreed to strive for a significant reduction in the current rate of biodiversity loss by 2010. While this agreement was obviously a step in the right direction, the important issue is how this reduction is going to be achieved. At the global level, there is now a range of international protocols and treaties in place that provide for the increased protection and reduced exploitation of species, particularly those that are classified as threatened or vulnerable. These include the Convention on the Conservation of Migratory Species of Wild Animals, the Convention on International Trade in Endangered Species, and the Convention on Biological Diversity.

Within many countries, in particular the more affluent nations, legislation carrying potent penalties is becoming increasingly important in deterring industrial polluters, poachers, and others threatening the future of endangered species and habitats. Laws that govern the appropriate use of terrestrial and marine habitats and resources are also becoming critically important.

It is widely agreed, however, that education and changes at grass-roots level—in communities, schools, and backyards—will ultimately ensure the future of Earth's biodiversity.

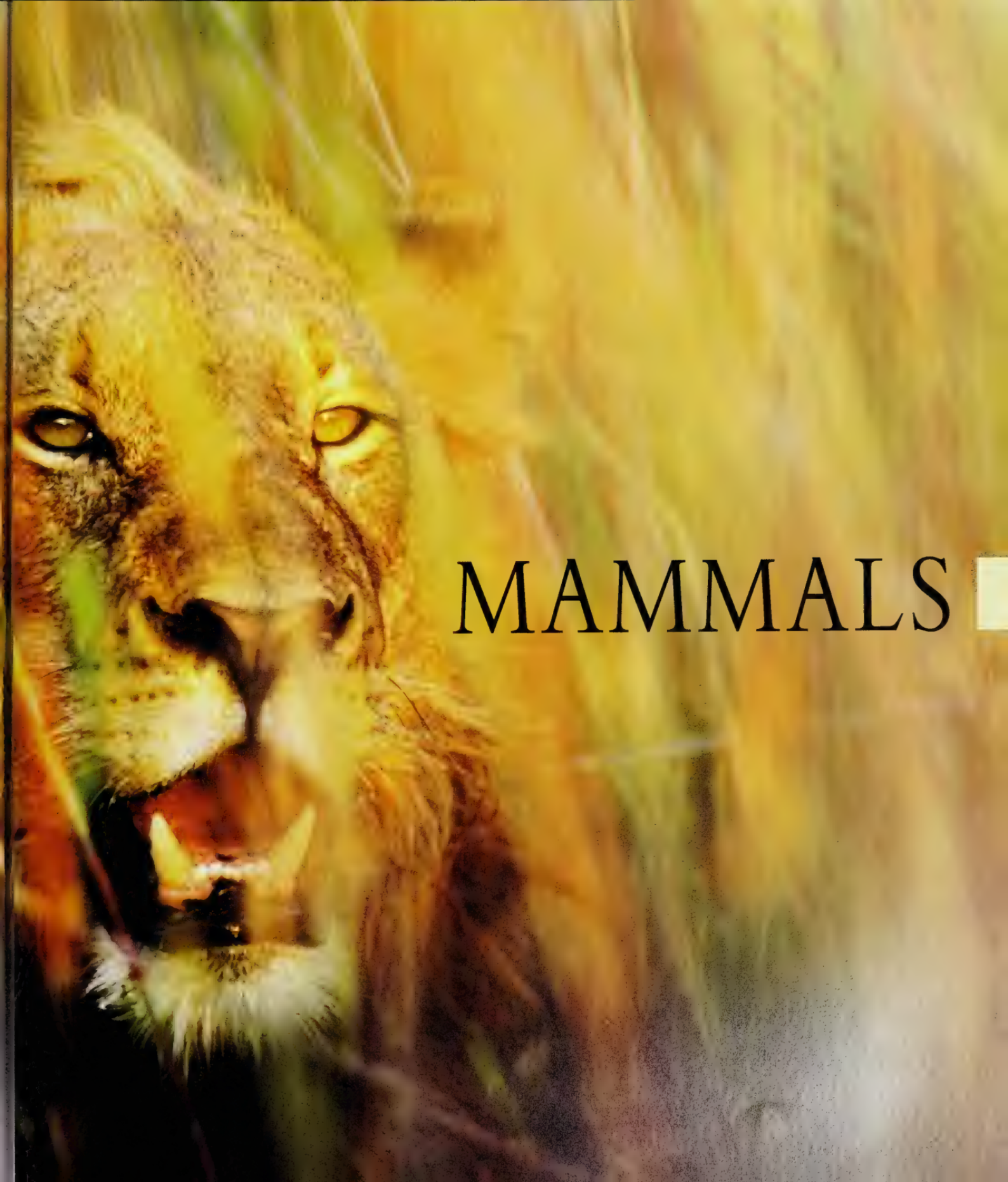


**Creating a safe haven** National parks, wildlife reserves, and other protected areas are the custodians of nature, critical to the survival of many thousands of species of wildlife. In Yellowstone National Park, north Wyoming, USA, conservation-dependent bison (*Bison bison*) roam in herds. However, when the park opened in 1872, there was no money to manage it and poaching went unchecked, reducing the last bison herd in the United States to 22 animals.

**Extinct in the wild** The rapid cultivation of the steppes of southern Russia and the Ukraine in the 19th century contributed to the disappearance of wild horses. The only subspecies still extant, Przewalskii's horse (*Equus ferus przewalskii*), survives only in captive breeding programs. While there are plans to return these animals to the wild, the success of this venture will depend on efforts to preserve their natural habitat.

**Mistaken identity** Although gentle unless provoked, the gray nurse shark (*Carcharias taurus*) is at risk from hunting because of its fierce look. Coupled with a very low reproduction rate, it is classified vulnerable. This species adapts readily to captivity, so is often seen in aquariums and marine parks.

**Modern-day Noah's arks** Captive breeding programs for disappearing animal species are already underway in zoos around the world, with the ultimate intention of rebuilding wild populations that are either threatened or already extinct. As a safeguard, however, scientists at several locations internationally have begun collecting and storing frozen tissue samples of endangered animals for which emerging cloning and genetic engineering techniques could prove to be a last resort. Work has already progressed toward cloning the Sumatran tiger (*Panthera tigris sumatrae*) and China's giant panda (*Ailuropoda melanoleuca*).

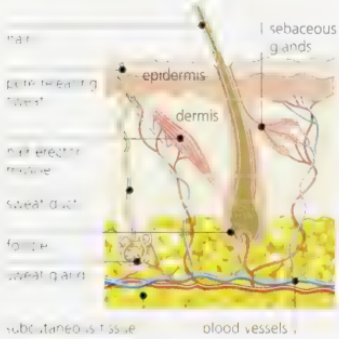


# MAMMALS

# MAMMALS

CLASS Mammalia
ORDERS 26
FAMILIES 137
GENERA 1,142
SPECIES 4,785

The astonishing diversity of the class Mammalia ranges from tiny field mice no bigger than a thimble, to the massive blue whale, which weighs 1,750 times more than a man. Their flexibility, adaptability, and intelligence have allowed mammals to occupy all continents and almost all habitats, exploiting niches on land, below ground, in trees, in the air, and in fresh and salt water. Despite their diverse body forms, mammals share some unique characteristics. Their defining feature is that the lower jaw bone, the dentary, attaches directly to the skull. Mammals are endothermic ("warm-blooded"), nurse their young with milk produced by mammary glands, and usually have hair on the body.




**In the skin** Mammalian skin is made up of two layers: the epidermis, an outer layer of dead cells, and the dermis, which contains blood vessels, nerve-endings, and glands. Muscles can raise or lower hairs to trap or release an insulating layer of air.

**In water** Streamlined for sleek movement through water, cetaceans such as dolphins have lost their body hair and rely instead on a layer of blubber as insulation.

## ORIGINS AND ANATOMY

Mammals evolved from a group of mammal-like reptiles that had a powerful bite and complex teeth. The first true mammals, with the distinctive jaw hinge between the dentary and the skull, emerged some 195 million years ago. These morganucodontids were nocturnal, shrew-like creatures, only about an inch (2.5 cm) long, that fed on insects. For the next 130 million years, Earth was dominated by dinosaurs, and mammals remained small. About 65 million years ago, however, a cataclysmic change in global climate led to the extinction of 70 percent of all animal species, including the dinosaurs. Mammals survived and began filling the newly empty niches, the start of a process that led to the remarkable variety of species that we see today.

The key to the survival of mammals during a period of severe climate change may have been the ability to regulate their internal body temperature through such methods as adjusting their metabolic rate or blood flow, and shivering, sweating, or panting. Endothermy allowed mammals to remain active regardless of extreme external temperatures and thus to colonize a great range of habitats.

One feature unique to mammals is the presence of hair on the body. Many mammals have a double coat of soft underfur and coarser guard hairs, which insulates against heat and cold. Specialized hairs form whiskers, or vibrissae, which are extremely sensitive to touch. Coat patterns can provide camouflage or communicate information, while spines and quills are modified hairs that create a defensive shield.

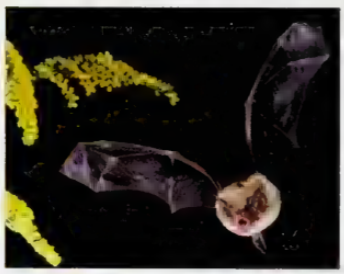
The skin of mammals contains a number of different types of glands. In females, mammary glands secrete milk for nourishing their young. Sebaceous glands produce an oily lubricant to protect and waterproof the fur. Sweat glands are important in temperature control, allowing many mammals to release sweat and cool down through its evaporation. Scent glands produce complex odors that convey a mammal's status, sexual condition, and other information. In some species, such as skunks, scent is also used in defense.

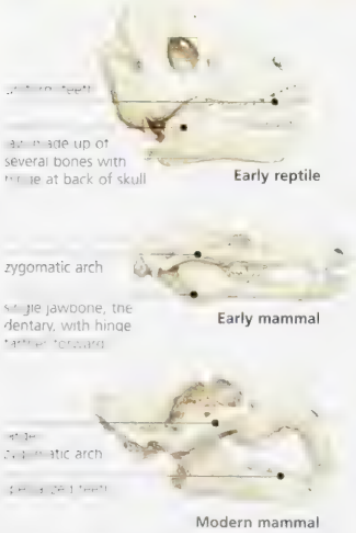
The brains of mammals are large (relative to body size) and complex. The sense of smell is important in communication. Color vision has arisen independently in a number of mammals, and binocular vision allows primates to judge distances. All mammals have three bones in the middle ear, and most have an external ear to collect sound.

**Fur and whiskers**

**Megaherbivore** The largest of all land mammals, the African elephant supports its great bulk on a herbivorous diet, collecting grasses, leaves, branches, flowers, and fruit with its dextrous trunk. As it must consume great quantities, it devotes three-quarters of its time to the search for food

**On the wing** The ability to fly, along with a sophisticated echolocation system, has allowed bats such as the little brown bat (*Myotis lucifugus*) to exploit the abundant food source of nocturnal flying insects






**Jaws and teeth** Mammals are the only animals that chew their food. They differ from their reptilian ancestors by having a single jawbone, powerful jaw muscles, a zygomatic arch, and complex teeth

**Captured prey** Meat provides a high-energy, easily digestible meal, but requires great effort and intelligence to catch. The snowshoe hare makes up between 35 and 97 percent of the Canadian lynx's diet

## DIVERSE LIFESTYLES

As mammals moved into different habitats, they adapted their anatomy, locomotion, diet, and social habits to suit their particular niche. Most terrestrial mammals walk on four feet, but some move on two. Some, such as bears, plant the entire sole on the ground, while others walk on just the digits (cats) or tips of the toes (deer). Many shelter below ground, with moles and some other efficient diggers spending almost their entire lives in their burrows. Trees are home for many primates, rodents, and other mammals. In some, grasping hands and feet provide a secure grip on branches and a prehensile tail acts as a fifth limb. A number of species have a gliding membrane that allows them to glide from tree to tree. Bats have developed true flight, with flapping wings allowing them to traverse great distances through the air. Many mammals are good swimmers, but aquatic mammals such as whales, dolphins, seals, and manatees have fully adapted to a life spent in water. Their shape has become streamlined and their limbs have been modified into flippers.

To fuel the constant regulation of their body temperature, mammals must consume a rich or plentiful diet. The structure of the jaw bones and muscles provides mammals with a powerful bite and the ability to cut and chew their food. Teeth are highly specialized and reflect the diet of the animal. The cheek teeth of carnivores, for example, are sharp for cutting flesh and bones; those of herbivores are broad for grinding plant matter; and omnivores have multicusped cheek teeth that enable them to chew both animals and plants. While many mammals are opportunistic feeders and will take advantage of any meal they come across, others are specialists. Some carnivores concentrate on insects and other invertebrates, or on small or large vertebrates. Herbivores may focus on fruit, leaves, or grasses. Plant-eaters tend to have a complex digestive system and depend on microorganisms in the gut to break down plant cellulose.

The adaptability of mammals is reflected in the diversity of their social organization. Adult mammals may be solitary, live in pairs or small family groups, or form harems, herds, or colonies. These groupings may be flexible and temporary, or highly stable and permanent. In all mammals, the fact that young are nourished by their mother's milk develops some kind of social bond.

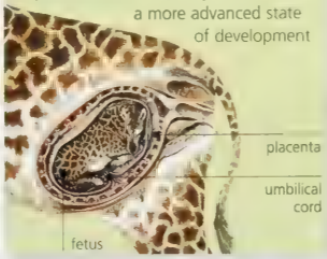
**Serious play** For many young mammals, such as these wrestling brown bear cubs play is an important way to learn the hunting and social skills they will need later in life

**Leaf-eating monkey** The douc langur lives in the rain-forest canopy, gripping branches with its grasping hands and feet and leaping from tree to tree. Its potbelly contains a complex digestive system to break down large quantities of leaves

**Frenzied feeder** To fuel a fast metabolism, the Eurasian common shrew must eat every few hours and consumes up to 90 percent of its weight in invertebrates each day. It shelters in a burrow, often taking over one abandoned by another species

### MAMMAL REPRODUCTION

In all mammals, the female's eggs are fertilized internally by the male's sperm. Monotremes lay the eggs after several days and incubate them externally until they hatch. Marsupials and placental mammals both give birth to live young. The young of marsupials have short gestations and are poorly developed at birth, but latch onto a teat and are nourished by the mother's milk. Placental mammals grow for longer inside the uterus, nourished by a placenta. At birth, they tend to be in a more advanced state of development



**Along for the ride** Although marsupials are born in an almost embryonic state, by the time they detach from the teat they are as developed as newborn placental mammals. A young koala leaves its mother's pouch at 7 months, but continues to ride on her back for another 5 months.

This may be rudimentary—the tree shrew, for example, visits its young only every couple of days for a brief nursing session, and some rodents are weaned after a few weeks. Many young mammals, however, remain dependent on the mother for many months or even years, as is the case with primates, elephants, and whales.

Mammals communicate with one another through scent, touch, sound, posture, and gesture. Both competition and cooperation are highly developed in many mammal species. Individuals of the same species will compete for territory, food resources, the right to mate, and social dominance. Social species may rely on fellow group members to help raise the young, to hunt cooperatively or share information about food sources, to warn of danger, and to deter predators.

**Herd mentality** Large grazing mammals often form herds, which provide many eyes and ears to detect danger, and lessen the chance that any one individual will be caught. Male Uganda kobs defend a mating territory known as a lek, which is visited by female herds (right) for breeding

# MONOTREMES

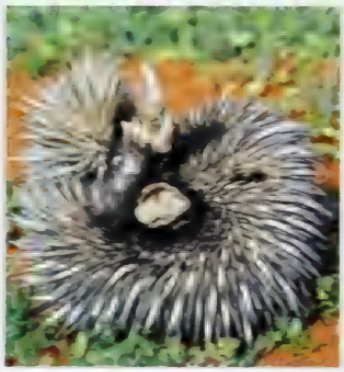
CLASS [illegible]
ORDER [illegible]
FAMILIES 2
GENERA 3
SPECIES 5

Like other mammals, monotremes are covered in fur, lactate to feed their young, and have a four-chambered heart, a single bone in the lower jaw, and three bones in the middle ear. They are unusual, however, because they lay eggs rather than give birth to live young, and also have some anatomical similarities to reptiles, such as extra bones in their shoulders. The two families in this order are Tachyglossidae, which includes two species of echidna, and Ornithorhynchidae, which contains just the platypus. With its duck-like bill, webbed feet, furred body, and beaver-like tail, the platypus has fascinated scientists since the first specimen was sent to Britain in 1799.

**Fossil platypus** This 15-million-year-old platypus skull is among the handful of monotreme fossils so far discovered. The fossil record suggests that monotremes originated at least 170 million years ago, when Australia was still part of Gondwana.

**Underwater forager** While [illegible] the platypus grows two canals, terminated with pits, in its bill. It uses its bill not only for locating food but [illegible] [illegible] opening them in [illegible] underwater.

**Spiny defense** [illegible]



## EGG-LAYING MAMMALS

Monotreme eggs are soft-shelled and hatch after about 10 days. Once hatched, the young rely on their mother's milk for several months, a dependence typical of mammals.

After mating in spring, female platypuses lay up to three eggs in a bankside nesting burrow and curl up to incubate them between the tail and body. The hatched young stay in the burrow for 3–4 months, feeding on milk that oozes from two nipple-like patches inside the mother's fur. After they emerge from the burrow the young are gradually weaned and eventually disperse to a largely solitary life. Wild platypuses have been known to live for at least 15 years.

During their winter mating season, several male short-nosed echidnas may follow a female for up to 14 days, conducting digging and pushing contests until one wins the right to mate. The female then lays a single egg into her pouch. After hatching, the young stay in the pouch until it develops spines and moves to a burrow. The mother lacks teats but her mammary glands open into patches of skin in her pouch. She may continue to feed the young for up to 7 months. A short-nosed echidna has survived for 49 years in captivity, but 16 years is the oldest recorded age in the wild.

Although little is known of the long-nosed echidna's breeding cycle, it is thought to resemble that of the short-nosed echidna.

Platypus
*Ornithorhynchus anatinus*

Fat stored in broad tail

Partially webbed hindfeet used as rudders

Webs of forefeet can be folded back to free claws for walking or digging

Each spine is an individual hair anchored in muscle

Pliable, sensitive bill helps platypus find food and navigate

Long snout can be used as a snorkel when crossing water

Short-nosed echidna
*Tachyglossus aculeatus*

Long-nosed echidna
*Zaglossus bruijni*

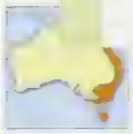
Mouth at end of snout

Walks with a rolling gait

CLASS M

ORDE

**Platyp** ... e mam... unusua... mamm... thick fu... riverbar... larvae a...



Up to 5½ lb (2.4 kg)
Solitary
Locally common

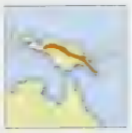
E. Australia, Tasmania, Kangaroo I., King I.

**Short-nosed echidna** Its stout body covered in long spines and shorter fur, this echidna walks with a rolling gait. It survives in a wide range of habitats, from semiarid to alpine, and feeds mainly on ants and termites.

Up to 14 in (35 cm)
Up to 4 in (10 cm)
Up to 15½ lb (7 kg)
Solitary
Locally common

Australia, Tasmania, New Guinea

**Long-nosed echidna** This echidna has more hair and fewer spines than the short-nosed species. Tiny spines on its tongue help capture the earthworms that make up the bulk of its diet.



Up to 31½ in (80 cm)
None
Up to 22 lb (10 kg)
Solitary
Endangered

New Guinea

## POISONOUS SPUR

The male platypus can use the spur on its rear ankle to inflict a paralyzing sting, making it one of the world's few venomous mammals. This feature may help it fight other males for territory and mates during the breeding season.

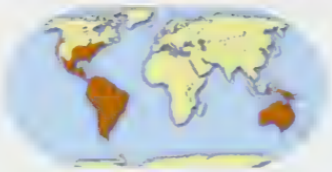
## CONSERVATION WATCH

**Long-nosed echidna** Found only in the alpine forests and grasslands of New Guinea, the current population of approximately 300,000 long-nosed echidnas is hunted by humans for food. It is also threatened by habitat loss, as roads and clearings are created through landclearing.

# MARSUPIALS

CLASS Mammalia
ORDERS 7
FAMILIES 19
GENERA 83
SPECIES 295

Commonly known as the pouched mammals, marsupials are virtually embryonic when born and must immediately drag themselves to their mother's teats, which are usually enclosed in a pouch of some kind. They latch firmly onto a teat for some weeks or months and come off only after reaching a level of development comparable to that of newborn mammals that have been nourished by a placenta in the womb. Most marsupials differ from placental mammals in other ways as well, with more incisors in each jaw, an opposable toe on the hindfoot, a relatively smaller brain, and a slightly lower body temperature and metabolism.



**Marsupial success** While some have flourished in the Americas, marsupials are most diverse in Australia and New Guinea, where there were no placental mammals. They have been introduced in New Zealand, Hawaii, and Britain

**Sibling rivalry** The common opossum may give birth to more than 50 young at a time, but only those that attach to one of her 13 nipples will survive. Once the young have developed further, but are still quite helpless, the mother will leave them in the nest while she forages for food.

## FINDING A NICHE

Once considered a single order, marsupials are much more diverse than any order of placental mammals and are now classified into seven orders. Of these, Didelphimorphia (containing American opossums), Paucituberculata (shrew opossums), and Microbiotheria (monito del monte) are found in the Americas, while the Australia–New Guinea region hosts Dasyuromorphia (quolls, dunnarts, marsupial mice, numbat), Peramelemorphia (bandicoots), Notoryctemorphia (marsupial moles), and Diprodontia (possums, kangaroos, koala, and wombats).

The fossil record suggests that marsupials and placental mammals diverged more than 100 million years ago. In North America and Europe, marsupials died out as placental mammals diversified. South America, on the other hand, was isolated from North America for about 60 million years, and marsupials evolved to fill a variety of ecological niches. When the Americas joined up, 2–5 million years ago, northern carnivores such as the jaguar soon displaced South America's large carnivorous marsupials, but small omnivorous marsupials persisted, with some, including the common opossum, recolonizing North America. It was in the region of Australia and New Guinea, however, that marsupials remained free of competition for the longest period and attained their greatest diversity.

**Life in the pouch** Wallabies, kangaroos, and other marsupials give birth to a small young that is [illegible] a relatively [illegible] pouch. Even after the young [illegible] to use the teats for suckling and sleeping.

### SIMILAR SOLUTIONS

Isolated for millions of years from the rest of the world, the marsupials of Australia and New Guinea occupy the same ecological niches as placental mammals fill elsewhere, and often display similar adaptations, a phenomenon known as convergent evolution. The striped possum, a marsupial of Australia and New Guinea, and the aye-aye, a placental mammal of Madagascar, are both tree-dwelling insectivores. Each species has one especially long finger that allows it to dig out wood-burrowing grubs.

Black-shouldered opossum
*Caluromysiops irrupta*

Forelimbs longer than hindlimbs

Bare-tailed woolly opossum
*Caluromys philander*

Naked, prehensile tail

Gray four-eyed opossum
*Philander opossum*

Common opossum
*Didelphis marsupialis*

Carries young on back until they are fully weaned at 3–4 months of age

Robinson's mouse opossum
*Marmosa robinsoni*

Opposable thumbs on all four paws for gripping thin branches and vines

## FACT FILE

**Black-shouldered opossum** Like many tree-dwelling mammals, this opossum has a prehensile tail for clinging to branches, and large, protruding eyes It feeds on the abundant fruit and nectar of its tropical forest home

Up to 12 in (30 cm)
Up to 16 in (40 cm)
Not known
Solitary
Vulnerable

N.W. South America

## ARBOREAL LIFESTYLES

American opossums have adapted to take advantage of the many ecological niches offered by a forest habitat Some live high in the treetops, feasting on the abundant fruit, nectar, and insects of the canopy. Others are primarily terrestrial, but will readily climb trees in search of food.

Bare-tailed woolly opossums actively climb through the upper canopy of trees as they look for fruit and insects.

Black-shouldered opossums are lethargic canopy dwellers that feed on fruit and nectar

Robinson's mouse opossums move along tree branches and vines with the help of a prehensile tail and may leap between gaps as they search for fruit and insects

Gray four-eyed opossums are opportunistic feeders, climbing up and down in search of fruit, insects, earthworms, and small vertebrates

[illegible]

## IN THE SWIM

The only truly aquatic marsupial, the yapok of Central and South America is superbly adapted to a life in water. It has long webbed toes on its hindfeet, water-repellent fur, and a pouch that closes during dives. It hunts its aquatic prey of fish, frogs, crustaceans, and insects mostly at night, and rests in a riverbank den by day.

***Strong stroke***
*The yapok uses its webbed hindfeet to move through the water, leaving its forefeet free to sift through the stream bottom for food.*

## MARSUPIAL ORIGINS

DNA studies have confirmed that the monito del monte of Argentina and Chile is the only living member of the Microbiotheriidae, a family of South American marsupials more closely related to Australian marsupials than to the other marsupials of South America. Together with fossil marsupials found in the Antarctic Peninsula, the monito del monte studies support the theory that marsupials spread from South America to Australia via Antarctica between 100 and 65 million years ago, when these continents formed a single landmass known as Gondwana.

***Separate populations***
*Marsupials radiated from South America to Antarctica and Australia. They flourished in Australia, where there was little competition, but vanished from Antarctica, which split away and moved south. When North and South America joined up again, northern carnivores displaced South America's large marsupials.*

*Little monkey*
*[illegible]*

Monito del monte (colocolo)
*Dromiciops gliroides*

White spot over each eye inspired common name of "four-eyed opossum"

Scaly tail longer than body

Brown four-eyed opossum
*Metachirus nudicaudatus*

Fat stored in base of tail for winter hibernation

Little water opossum
*Lutreolina crassicaudata*

Three-striped short-tailed opossum
*Monodelphis americana*

Yapok (water opossum)
*Chironectes minimus*

Patagonian opossum
*Lestodelphys halli*

Sparsely haired tail shorter than body

Southern short-tailed opossum
*[illegible]*

Ecuadorean shrew-opossum
*Caenolestes fuliginosus*

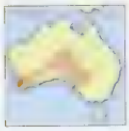
## FACT FILE

**Tasmanian devil** About the size of a terrier and now the largest carnivorous marsupial, the Tasmanian devil will hunt live prey such as possums and wallabies, but prefers to scavenge. It screeches or barks when threatened

Up to 25½ in (65 cm)
Up to 10 in (26 cm)
Up to 20 lb (9 kg)
Variable
Uncommon

Tasmania

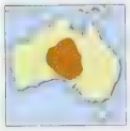
**Numbat** The only marsupial that is fully active by day, the numbat spends most of its time looking for termites, which make up almost its entire diet It digs termites from loose earth with its front claws and captures them with its long, sticky tongue



Up to 11 in (27.5 cm)
Up to 8½ in (21 cm)
Up to 24½ oz (700 g)
Solitary
Vulnerable

S.W. Australia
Former range

**Southern marsupial mole** Below the desert sands of Australia, the marsupial mole searches for burrowing insects and small reptiles. Instead of building a tunnel, it "swims" through the ground, allowing the sand to collapse behind it



Up to 6½ in (16 cm)
Up to 1 in (2.5 cm)
Up to 2½ oz (70 g)
Solitary
Endangered

C. Australia

## EXTINCT TIGER

**Thylacine** The largest carnivorous marsupial to survive into historical times, the thylacine resembled a wolf, but had a distinctive striped coat and a long, stiff tail. It mainly hunted birds, wallabies, and smaller mammals Although competition with the dingo led to its disappearance from mainland Australia 3,000 years ago, the thylacine was widespread on Tasmania until Europeans arrived. A reputation [illegible] killing sheep soon saw it [illegible] to extinction, with the last cont[illegible] sightings occurring in the 19[illegible]

## FACT FILE

**Kowari** In Central Australia's stony deserts and dry grasslands, this little marsupial carnivore preys on insects and small birds, reptiles, and mammals. To survive in the arid climate, the kowari shelters in burrows and obtains all its moisture from its food, eliminating the need to drink water.

- Up to 7 in (18 cm)
- Up to 5½ in (14 cm)
- Up to 5 oz (140 g)
- [illegible]
- Vulnerable

## ANNUAL DIE-OFF

One of the most unusual life-cycles occurs in all *Antechinus* and two *Phascogale* species, which breed just once annually. At the same time every year, following an exceptionally intense 2-week mating season, all the males within a population die off. Their vigorous mating efforts induce very high stress levels, which allow them to forgo food in favor of reproduction but also make them vulnerable to diseases such as stomach and intestinal ulcers. Females may live for a second year, but usually produce only one or two litters in their lifetime.

***Sole parent*** *The female dusky antechinus* [illegible]

## SLOWING DOWN

Dunnarts and other small insectivorous marsupials sometimes enter periods of torpor, during which the metabolism [illegible] and the heart and respiratory [illegible] slow down. By conserving [illegible] this state reduces the need to [illegible]

*A winter's tail* [illegible]

## FACT FILE

**Bilby** The bilby is a powerful digger and may build up to 12 burrows in its home range. It can be distinguished from other bandicoots by its long ears.

Up to 22 in (55 cm)
Up to 11½ in (29 cm)
Up to 5½ lb (2.5 kg)
Solitary
Vulnerable

C Australia
Former range

**Southern brown bandicoot** This omnivore digs for insects and worms with its sharp front claws, killing the prey by stamping on it repeatedly. It also eats fruit, seeds, and fungi.

Up to 14 in (36 cm)
Up to 5½ in (14 cm)
Up to 2½ lb (1.6 kg)
Solitary
Uncommon

Coastal S and E Australia, Tasmania

## BANDICOOTS

The relationship of the omnivorous bandicoots to other marsupials is unclear. They have an arrangement of teeth similar to that of carnivorous marsupials, but they also have fused toes on the hindfoot, a feature known as syndactyly that is shared with herbivores such as kangaroos and wombats. Bandicoots are divided into two families: the mainly Australian Peramelidae, comprising the *Perameles* and *Isoodon* species, and the mainly New Guinean Peroryctidae, including the spiny bandicoots.

***Rapid reproduction***
After a short gestation period lasting 10 days, bandicoot young develop quickly and may reach sexual maturity in either 90 days

## CONSERVATION WATCH

**Saving the bilby** During the past 100 years, the number and range of bilbies have been dramatically reduced, with much bilby habitat lost to farming. Introduced species have also taken their toll, cats, foxes and feral pigs carrying rabbits and cattle, sheep, goats and camels competing for food. Now, captive-bred the species is being bred [illegible] and then released into the wild. This [illegible] an attempt to prevent [illegible]

## FACT FILE

**Spotted cuscus** This rain-forest marsupial spends most of its time in trees, sleeping by day in a small bed of leaves and feeding at night on a diet of fruit, flowers, and leaves. While males are white with gray spots, females tend to be uniformly gray and unspotted. Intensively hunted in New Guinea, the spotted cuscus is also threatened by habitat loss from logging and farming.

- Up to 23 in (58 cm)
- Up to 17½ in (45 cm)
- Up to 11 lb (4.9 kg)
- Solitary
- Vulnerable

N. Australia, New Guinea, some islands

## MOUNTAIN MEALS

The only Australian marsupial to live above the snowline, the mountain pygmy-possum makes the most of its habitat's resources by eating a wide range of food types, but specializing according to the season. During the warmer months, it feeds mostly on Bogong moths, which migrate annually to the Australian Alps, and also eats small amounts of other insects. As the moths become less abundant around January, it switches to seeds and berries, storing caches of these for the cold winter months ahead.

- Up to 4½ in (12 cm)
- Up to 6 in (15 cm)
- Up to 3 oz (80 g)
- Solitary
- Endangered

Australian Alps

***A mouthful of moth***
*During the warmer, active months, Bogong moths provide food for the mountain pygmy-possum, making up between a third and all of its diet.*

## CONSERVATION WATCH

**Mountain pygmy-possum** With a total population of fewer than 2,000 adults, this marsupial species is classified as endangered. Once believed to be extinct, the mountain pygmy-possum has a very restricted range in the mountains of eastern Australia. Much of its habitat has been destroyed or fragmented by the building of roads, dams, and ski resorts, and by recent wildfires.

Bobuk
(mountain brushtail possum)
*Trichosurus caninus*

Gray cuscus
*Phalanger orientalis*

Spotted cuscus
*Spilocuscus maculatus*

Brushtail possum
*Trichosurus vulpecula*

Feathertail glider
*Acrobates pygmaeus*

Gliding membrane extends from wrist to knee

Feather-like arrangement of fur on tail unique among mammals

Prehensile tail covered in thick scales

Scaly-tailed possum
*Wyulda squamicaudata*

Mountain pygmy-possum
*Burramys parvus*

Rock ringtail possum
*Petropseudes dahli*

Green ringtail possum
*Pseudochirops archeri*

Lemuroid ringtail possum
*Hemibelideus lemuroides*

Common ringtail possum
*Pseudocheirus peregrinus*

Two opposable digits on each front paw

Highly arboreal, rarely descends to ground

Herbert River ringtail possum
*Pseudochirulus herbertensis*

Tail tightly curled when not in use

## FACT FILE

**Rock ringtail possum** By day, this possum stays cool and safe in rock crevices, emerging at night to feed in trees. Males and females share care of the young equally, a level of male participation that is rare in mammals and unknown in other marsupials

Up to 15½ in (39 cm)
Up to 10½ in (27 cm)
Up to 4½ lb (2 kg)
Pair
Locally common

N. Australia

**Green ringtail possum** Bands of black, yellow, and white on its hairs combine to give this possum a distinctive lime-green appearance, helping it to remain hidden from predators in the trees of its rain-forest home. It feeds primarily on leaves.

Up to 15 in (38 cm)
Up to 15 in (38 cm)
Up to 3 lb (1.3 kg)
Solitary
Near threatened

N.E. Australia

**Common ringtail possum** Most of this nocturnal animal's diet is made up of eucalyptus leaves, but it also feeds on fruit, flowers, and nectar, even eating rosebuds in urban areas. Small family groups live in dreys—nests of bark, twigs, and ferns built in the fork of a tree or in dense shrubs.

Up to 15 in (38 cm)
Up to 15 in (38 cm)
Up to 2 lb (1 kg)
Solitary
Locally common

E. Australia

## A POISONOUS DIET

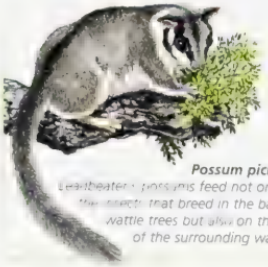
The common ringtail primarily eats eucalyptus leaves, which are usually toxic and lacking in nutritional value. A specialized digestive system featuring an enlarged cecum (a pouch in the large intestine) detoxifies the leaves and then releases soft fecal pellets that the possum can eat. Any undigested material is then expelled as hard pellets. To cope with this low-energy diet, the ringtail has a slow metabolism.

## FACT FILE

**Leadbeater's possum** This possum has exploited a niche created by the wildfire ecology of its highland forest home. When fires sweep through an area, they may kill some old trees and clear the way for new growth of wattle trees. Family groups may share nests of shredded bark in the hollow center of large trees, feeding on the insects that breed in the bark.

SE Australia

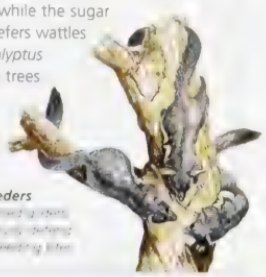
- Up to 6¼ in (17 cm)
- Up to 7 in (18 cm)
- Up to 5¾ oz (160 g)
- Pair, family group
- Endangered



***Possum pickings***
*Leadbeater's possums feed not only on the insects that breed in the bark of wattle trees but also on the sap of the surrounding wattles.*

## SAP SUCKERS

A membrane extending from the wrists to the ankles allows gliders to travel substantial distances through the air from one feeding tree to another. Once landed, they cut notches in the bark with their teeth and lap up the sap and gum. The yellow-bellied glider targets a number of eucalypt species, while the sugar glider prefers wattles and *Eucalyptus resinifera* trees.



***Sticky feeders***
*Gliders [illegible] by [illegible] and [illegible] their sap-feeding [illegible]*

## CONSERVATION WATCH

**Specialized nests** The Leadbeater's possum relies on a very specialized habitat, nesting in hollow old-growth trees that can take up to 150 years to become suitable. Presumed extinct after a wildfire in 1939 that burned nearly 70 percent of its range, Leadbeater's possums now number about 5,000, but are endangered by timber logging. Even with conservation measures, there may not be enough remaining nesting sites to sustain this species.

**Greater glider**
*Petauroides volans*

**Yellow-bellied glider**
*Petaurus australis*

Gliding membrane extends from elbows to ankles

Belly fur can be whitish, yellow, or orange

**Sugar glider**
*Petaurus breviceps*

Each hindfoot has an opposable big toe as well as two partially fused toes used for grooming

Long, bushy tail acts as a rudder during glides

**Leadbeater's possum**
*Gymnobelideus leadbeater*

Koala
*Phascolarctos cinereus*

Feeds almost solely on eucalyptus leaves

Needle-sharp claws can firmly grip smooth tree trunks

Pointed snout probes flowers for nectar, and long, bristly tongue collects pollen

Honey possum
*Tarsipes rostratus*

Elongated fourth finger with hooked nail used to extract wood-boring grubs

Striped possum
*Dactylopsila trivirgata*

Common wombat
*Vombatus ursinus*

Muzzle covered in fur

Powerful forelimbs with massive paws and long, sturdy claws used for digging burrows

Southern hairy-nosed wombat
*Lasiorhinus latifrons*

## FACT FILE

**Koala** Spending virtually their entire lives in trees, koalas sleep for 18 hours a day and feed at night, preferring the leaves of five particular eucalypt species. During the breeding season, competing males bellow throughout the night. The female gives birth to a single young, which she carries on her back once it is old enough to leave the pouch

Up to 32½ in (82 cm)
None
Up to 33 lb (15 kg)
Solitary
Near threatened

S. & E. Australia

**Southern hairy-nosed wombat** Nicknamed "the bulldozer of the bush," this wombat can run at high speeds in play or fright. It shelters from the heat of the day in group warrens, emerging at night to feed on grasses, roots, bark, and fungi

Up to 37 in (94 cm)
None
Up to 70½ lb (32 kg)
Solitary
Locally common

S. Australia

## GOING UNDERGROUND

The common wombat relies on its powerful front limbs and claws to dig an extensive warren of burrows, which can be up to 20 inches (50 cm) wide and 100 feet (30 m) long. Unlike its cousin, the southern hairy-nosed wombat, which shares a warren with up to 10 others, the common wombat spends its time underground alone

***Elaborate design***
*A wombat warren usually has several entrances, side tunnels, and sleeping chamber*

## CONSERVATION WATCH

**Northern hairy-nosed wombat** With a population of about 70 individuals confined to a single national park in Queensland, Australia, the northern hairy-nosed wombat (*Lasiorhinus krefftii*) is classified as critically endangered. Once widely hunted for its thick fur, this wombat species continues to decline as cattle herds compete for its food of grasses.

## FACT FILE

**Goodfellow's tree kangaroo** Limbs [illegible] length and sharp claws help this marsupial climb through rain-forest trees, where it shelters in small groups and feeds on leaves and fruit.

**Northern nail-tailed wallaby** Named after the horny spur on its tail, this animal spends the day in a shallow nest [illegible] the ground that grows in its [illegible] home.

**Brush-tailed bettong** Adapted to a range of habitats, from temperate forests to arid grasslands, the brush-tailed bettong [illegible] scrounge green [illegible] the ground.

**Red-legged pademelon** The only ground-dwelling wallaby to live in wet tropical forests, this [illegible] creature searches the dense understory for food such as leaves, fruit, bark, and [illegible].

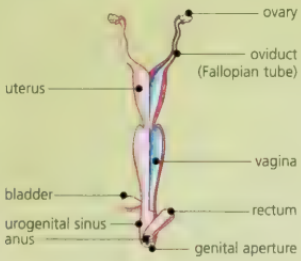
## CONSERVATION WATCH

**Brush-tailed bettong** Although it once ranged over 60 percent of Australia, the brush-tailed bettong is now restricted to a handful of small areas, a victim of predation and competition from introduced species, and habitat loss from farming. In recent years, captive breeding programs and fox controls [illegible] enabled the reintroduction of [illegible] marsupial in South Australia.

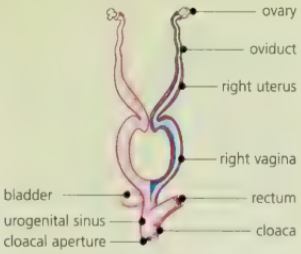
# MAKING MARSUPIALS

The unique nature of marsupial reproduction begins with the anatomy of the parents. On the outside, the female system seems simpler than in placental mammals, with a single opening, called a cloaca, for the digestive and reproductive tracts. Inside, however, there is a double reproductive tract involving two uteri, each with its own vagina. Many male marsupials have a forked penis, which directs semen into both vaginas. A pregnant female develops a third vagina as a birth canal. After a short gestation, ranging from 12 days in some bandicoot species to 38 days in the eastern gray kangaroo, almost embryonic young are born that crawl to a teat, which is usually protected by a pouch. Once the young are fully formed, they leave the teat, but are weaned gradually, usually taking several months to become fully independent.

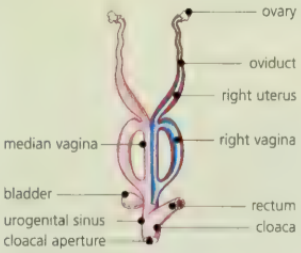
**Doubling up** Featuring two uteri and two vaginas, the internal anatomy of female marsupials differs markedly from that of placental mammals. Once a female marsupial becomes pregnant, she develops a third canal for the birth of her young.




***Female placental mammal***
*This system has a single uterus and a single vagina, and separate openings for the reproductive and digestive tracts.*




***Non-pregnant female marsupial***
*Two uteruses lead to two vaginas. Both vaginas and the rectum lead to a single opening, which is known as the cloaca.*




***Pregnant female marsupial***
*A median birth canal develops during pregnancy. In most marsupial species, this disappears after the birth, but it remains as a permanent structure in kangaroos and the honey possum.*

***1. On their way***
*Newborn eastern quolls (Dasyurus viverrinus) crawl through their mother's belly hairs to find the teats in her pouch. At this stage, their eyes, ears, and hindlimbs are embryonic, but their nostrils, mouth, and forelimbs are all large and functioning. While as many as 30 quolls may be born, only the 6 or so that attach to the mother's teats will survive*

**Pouch time** A marsupial is tiny when born—a red kangaroo's newborn is 0.003 percent of the mother's weight, while a human baby is about 5 percent of its mother's weight. By the end of weaning, however, the ratio of a marsupial offspring's weight to the mother's is comparable to that of placental mammals.

**Raising a family** Most kangaroos and wallabies give birth to a single young, but mate within a day or two of its birth. When a female is suckling a joey that can move in and out of the pouch, she usually also has a pouch embryo—a younger offspring attached to a teat inside the pouch. In addition, she is likely to be carrying a blastocyst, a fertilized egg that stays quiescent until the pouch embryo is ready to detach from the teat.

***2. Latched on***
*The young quolls remain firmly attached to their mother's teats during 8 weeks of passive development, when they are known as pouch embryos. To avoid the danger of choking, a large glottis shuts off a baby's mouth from its air passage*

***3. Into the world***
*Once fully formed, the young quolls detach from the teats and leave the pouch, but remain with the mother for some months, clinging to her back while she is foraging, sharing a den for sleeping, and feeding on her milk*

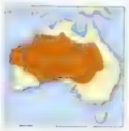
## FACT FILE

**Parma wallaby** The smallest wallaby, this animal was believed to be extinct for decades until its rediscovery in 1965 on New Zealand's Kawau Island, where it had been introduced long before. Other surviving populations were later found in Eastern Australia.

- Up to 21 in (53 cm)
- Up to 21¼ in (54 cm)
- Up to 13 lb (6 kg)
- Solitary
- Near threatened

E. Australia

**Red kangaroo** The largest of the marsupials, the red kangaroo usually hops slowly, but can reach speeds of 35–45 miles per hour (55–70 km/h). Males of this species have a reddish coat, but females are bluish gray.



- Up to 55 in (140 cm)
- Up to 39 in (99 cm)
- Up to 187 lb (85 kg)
- Herd
- Common

Australia

### MOB MEMBERSHIP

Large kangaroos often congregate in groups, or mobs, of 50 or more, a strategy that helps deter predators such as dingoes. While males are not territorial, their access to mates depends on their position in the mob's hierarchy, which tends to be based on size. A dominant male Eastern gray kangaroo may father up to 30 young in a season, but most males never get the chance to mate.

***Kickboxing*** *Male kangaroos sometimes fight [illegible] dominance [illegible] with their [illegible]*

## CONSERVATION WATCH

Of the 295 species of marsupials, 56% are listed on the IUCN Red List, as follows:

- 10 Extinct
- 5 Critically endangered
- 27 Endangered
- 47 Vulnerable
- 45 Near threatened
- .. Data deficient

# XENARTHRANS

**CLASS** Mammalia
**ORDER** Xenarthra
**FAMILIES** 4
**GENERA** 13
**SPECIES** 29

Some of the world's most bizarre animals—anteaters, sloths, and armadillos—make up Xenarthra, an ancient order that was once much more diverse and included ground sloths larger than elephants, and armored mammals bigger than polar bears. Originating in and confined to the Americas, xenarthrans all have extra joints, known as xenarthrales, in the lower spine, which limit twisting and turning but strengthen the lower back and hips, a particular advantage for the burrowing armadillos. The brains of xenarthrans are small and their teeth are rudimentary or, in the case of anteaters, absent. A slow metabolism has allowed these species to take advantage of narrow niches.

**Clingy child** Following a gestation period of a year, female sloths give birth to a single young and nurse it for roughly a month. The young then stays with the mother for several months, clinging to her thick fur with its curved claws.

**Toilet stop** About once a week, a sloth leaves the trees to defecate on the ground. Unable to support its body weight, the animal use its long forelimbs to drag itself along. The toilet site is carefully selected, suggesting that the sloth may be fertilizing favorite feeding trees.

**BUILT-IN BLANKET**

The giant anteater spends up to 15 hours a day resting. Its digs a shallow depression in the ground and lies down, curling its bushy, fan-like tail around itself. As well as providing warmth, this arrangement helps to disguise the anteater when it is at its most vulnerable.

**Digging deep** An anteater's sharp front talons can rip into concrete-like termite mounds, allowing its long, sticky tongue to collect the insects. An attack causes little permanent damage to a nest, however, because it lasts just a few minutes and only a small number of termites are eaten. The mound is repaired by the surviving termites.

## SLOW AND STEADY

The low metabolic rate and body temperature of anteaters and sloths have enabled them to become highly specialized feeders, exploiting food sources that are abundant but low in energy content. Armadillos, on the other hand, have a varied diet, but live in deep underground tunnels, where their slow metabolism helps them to avoid overheating.

Ranging from the terrestrial giant anteater to the tree-dwelling silky anteater and tamanduas, anteaters use their keen sense of smell to detect ants and termites. From an especially long, tubular snout, an even longer tongue darts out, covered in tiny spines and sticky saliva to capture the prey.

Remarkably sluggish, sloths spend almost all their waking hours feeding on forest leaves, consuming such quantities that a full stomach can account for nearly a third of their body weight. Inside a sloth's multichambered stomach, toxins in the leaves are neutralized and the leaves slowly break down, taking a month or more to be fully digested.

With a carapace of bony horn-covered plates, armadillos are not only shielded from predators but are also at ease foraging in dry, thorny vegetation. While much of their diet is made up of invertebrates, they may also consume fruit and small reptiles. They use their powerful limbs and sharp claws to excavate up to 20 burrows in their home range and to dig for prey.

## FACT FILE

**Maned three-toed sloth**

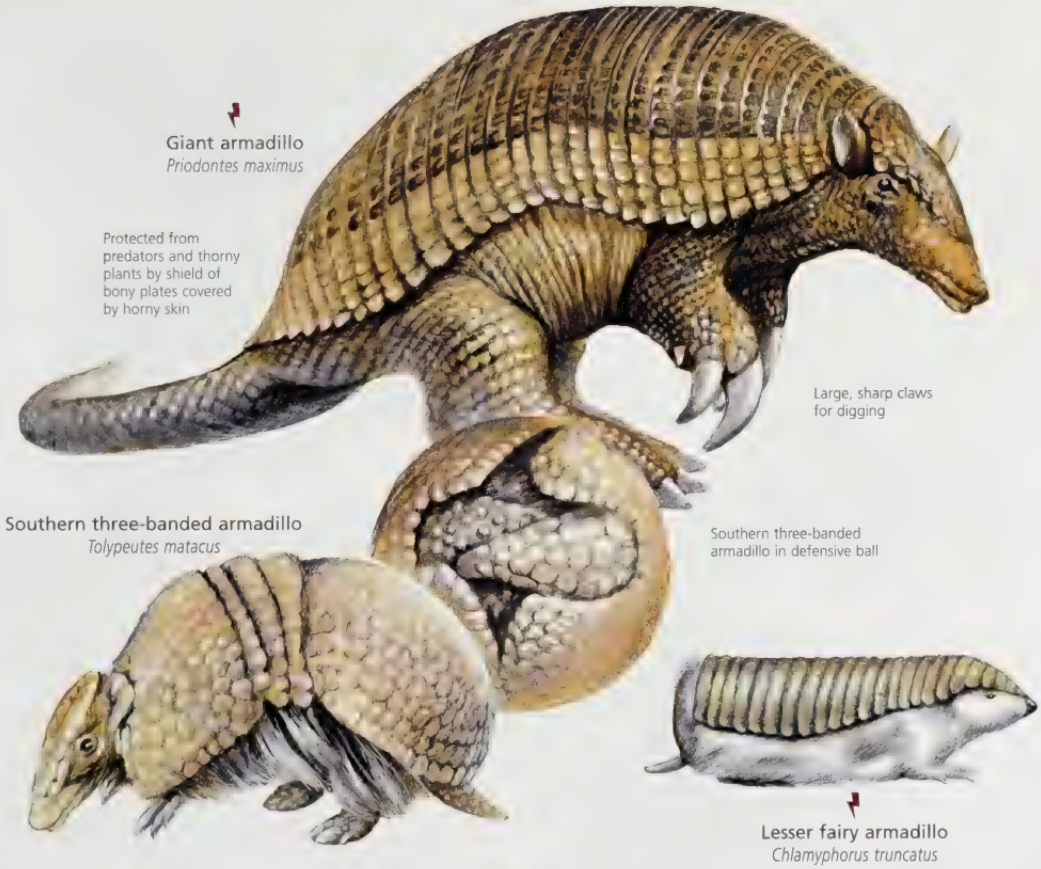
**Silky anteater**

## IDENTICAL QUADRUPLETS

**Family likeness**

## CONSERVATION WATCH

**Vulnerable sloths**



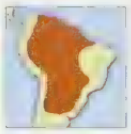

# PANGOLINS

**CLASS** Mammalia
**ORDER** Pholidota
**FAMILY** Manidae
**GENUS** *Manis*
**SPECIES** 7

A covering of horny body scales growing from a thick underlying skin distinguishes pangolins from all other mammals. An extraordinary tongue, longer than the animal's head and body, is coiled in the animal's mouth when at rest, but can be extended and flicked into ant nests and termite mounds. Pangolins lack teeth, relying instead on powerful muscles and small pebbles in their stomachs to grind up their food. Terrestrial species, such as the giant ground pangolin, dig out underground burrows for shelter during the day. The long-tailed pangolin and other tree-dwelling species have a prehensile tail for help with climbing, and curl up into balls in tree hollows when resting.

## FACT FILE

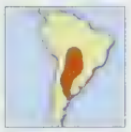
**Giant armadillo** About the size of a German shepherd dog, the giant armadillo has huge front claws that it uses for building its own burrows and for digging into termite mounds. While it prefers termites, it will also eat other insects and worms, snakes, and carrion



Up to 39½ in (100 cm)
Up to 21½ in (55 cm)
Up to 66 lb (30 kg)
Solitary
Endangered

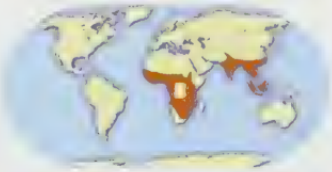
N. South America

**Southern three-banded armadillo** Unlike other armadillos, which will speedily burrow if threatened, this species can roll itself into a tight ball, so that it is entirely protected by armor It may leave a slight opening that can snap shut on the probing paw of a predator. This defense strategy is ineffective against humans, however, who hunt this armadillo for food.



Up to 10½ in (27 cm)
Up to 3 in (8 cm)
Up to 2½ lb (1.2 kg)
Solitary
Near threatened

C. South America



**Asia and Africa** Pangolins are found in much of Southeast Asia and subtropical Africa. While the Asian species have external ears and grow hair at the base of their scales, the African species lack external ears and have no scales on the tail's underside. Like anteaters in the Americas and echidnas in Australia and New Guinea, pangolins are specialized to feed on ants and termites.

## CONSERVATION WATCH

**Hunted scales** Pangolins have been relentlessly hunted, prized as meat in Africa and for the medicinal value of their scales in Asia. Dest[illegible] of their rain-forest habitat threatens these specialized creatures. The Cape pangolin (*Manis temminc[illegible]* of Africa, as well as all of the th[illegible] Asian species—the Indian pangolin (*M. crassicaudata*), Malayan pangolin (*M. javanica*), and Cl[illegible]golin (*M. pentadactyla*) [illegible]d on the IUCN Red List as near th[illegible]reatened

# INSECTIVORES

CLASS Mammalia
ORDER Insectivora
FAMILIES 7
GENERA 68
SPECIES 428

Small, quick creatures with long, narrow snouts, shrews, moles, hedgehogs, and other insectivores make up a diverse order whose classification is much debated. While they share primitive features such as a small, smooth brain, simple bones in the ear, and rudimentary teeth, many also display specializations such as burrowing adaptations, defensive spines, or poisonous saliva. Insectivores were named after their tendency to eat insects, but many will take advantage of any available food source and readily consume plants and other animals. Usually shy and nocturnal, they rely on acute senses of smell and touch rather than vision and have very small or even minute eyes.

**Worldwide spread** While three insectivore families—hedgehogs and moonrats; moles and desmans; and shrews—are found in much of the world, solenodons, tenrecs, and otter shrews are highly localized

**All in a row** To avoid getting lost, young of the white-toothed shrew (*Crocidura russula*) "caravan," form a chain behind the mother by tenaciously gripping the rear end of the animal in front

**Fast food** Because of their extremely fast metabolisms, shrews must eat vast amounts for their size and usually live where food is abundant. The diet of the Eurasian water shrew (*Neomys fodiens*) features aquatic invertebrates, fish, and frogs

**Opportunity knocks** Insectivores are often opportunistic feeders, prepared to eat a wide variety of prey and plants. The Western European hedgehog mostly eats invertebrates such as earthworms, slugs, beetles, and grasshoppers, but will also devour vertebrate carrion and young birds

***Flat-footed walkers***

## CONVERGING SPECIES

The order Insectivora contains numerous examples of convergent evolution, with animals in similar habitats displaying similar behaviors or physical adaptations, even though they are not closely related.

Some insectivores have exploited an aquatic niche. The desmans of Europe and the web-footed tenrec (*Limnogale mergulus*) of Madagascar evolved in total isolation from each other, but they share a dense, waterproof coat, a streamlined body, partially webbed feet, a long tail that acts as a rudder, and specialized mechanisms for breathing and detecting underwater prey.

European moles and African golden moles are very distantly related, with true moles evolving from a shrew-like animal, and golden moles more closely related to tenrecs. Nevertheless, they look very much alike and both display adaptations to a burrowing lifestyle. Their bodies are compact and cylindrical, their limbs are short and powerful, with large digging claws on the forefeet, and their eyes are minute and hidden by fur or skin.

The hedgehogs of Europe and the tenrecs of Africa employ similar means of self-defense. Both have a thick coat of spines and will curl up when threatened, becoming a spiky ball to discourage predators.

The solenodons of Cuba and Hispaniola and the tenrecs of Africa appear to have developed echolocation, a method of locating prey by bouncing sounds off the surrounding environment.

Raises stiff hairs along neck into a crest when threatened

Covered in coarse hair and sharp spines

**Tail-less tenrec (common tenrec)**
*Tenrec ecaudatus*

**Large-eared tenrec**
*Geogale aurita*

Thick, scaly tail

Strong claws for digging insects, worms, and small lizards out of leaf litter

**Cuban solenodon**
*Solenodon cubanus*

Flattened head allows nostrils, eyes, and ears to stay above water's surface while body is submerged

Dense fur traps insulating layer of air when swimming

Fused toes on hindfoot used for grooming

**Giant otter shrew**
*Potamogale velox*

Locates prey using sensitive whiskers

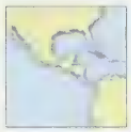
Tail used for propulsion and steering in water

**Ruwenzori otter shrew**
*Micropotamogale ruwenzorii*

Webbed feet

## FACT FILE

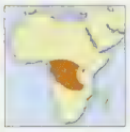
**Cuban solenodon** Like *Solenodon paradoxus* of Hispaniola, the Cuban solenodon releases venomous saliva through a groove in one of its lower incisors. It may use the venom to paralyze larger prey such as frogs. With only a handful of individuals seen in the wild since the 1980s, the future of this species is uncertain.



- Up to 15 in (39 cm)
- Up to 9½ in (24 cm)
- Up to 2 lb (1 kg)
- Solitary
- Endangered

E. Cuba

**Giant otter shrew** Appearing in African folklore as part fish, part mammal, the giant otter shrew swims powerfully through the water with thrusts of its laterally flattened tail. It hunts at night, searching out prey such as crabs, frogs, fish, and insects by scent and touch. After foraging, it returns to its burrow through an underwater entrance.

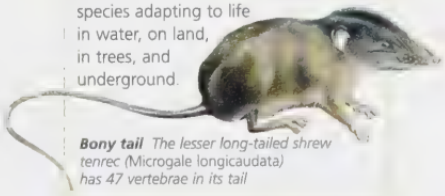


- Up to 14 in (35 cm)
- Up to 11½ in (29 cm)
- Up to 14 oz (400 g)
- Solitary
- Endangered

C. Africa

## TENRECS OF MADAGASCAR

Among the first mammals to arrive on the island of Madagascar after its separation from mainland Africa 150 million years ago, tenrecs had few competitors. They diversified to fill a variety of ecological niches, with species adapting to life in water, on land, in trees, and underground.



***Bony tail*** *The lesser long-tailed shrew tenrec (Microgale longicaudata) has 47 vertebrae in its tail*

## CONSERVATION WATCH

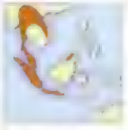
**Declining solenodons** Both species of solenodon are listed as endangered, with populations taking a dramatic dive since Europeans colonized the West Indies. Because they had few natural predators on their island homes, solenodons never developed effective defenses and [illegible] prey for introduced [illegible] such as mongooses and domestic dogs and cats. Clearing for agriculture has also taken its toll, destroying the forest [illegible] insectivores.

## FACT FILE

**Moonrat** The smell of rotting [illegible] flowers, or ammonia may indicate the presence of a moonrat, which produces a strong scent from two glands near the anus. The animal uses this powerful odor to mark its territory. A solitary creature, the moonrat will emit threatening hiss-puffs and [illegible] rears it encounters another member of its species. It rests by day in hollow logs or crevices, and hunts its prey of insects, earthworms, crustaceans, molluscs, frogs, and fish at night.

Malay Peninsula, Sumatra, Borneo

**Lesser moonrat** Spending most of its time on the floor of humid mountain forests, this animal moves in short leaps and sometimes climbs through bushes. It often nests under rocks.



Mindanao, Mindanao, Indonesia

**Hottentot golden mole** A horny pad on the nose and four clawed toes on each forepaw help this golden mole build extensive tunnel networks beneath the surface. Like the unrelated Australian marsupial mole, it is sightless with fur covering its residual eyes.

South Africa

## CONSERVATION WATCH

**Population pressure** Among the 1,000 rarest animals in the world, the giant golden mole *Chrysospalax trevelyani* survives in just a few small areas in South Africa's East Cape region. Already endangered, the species is under ever greater pressure as the human population increases. It has been wrongly blamed for crop damage that was actually caused by mole-rats and other rodents. Predation by domestic dogs has had a serious impact, as has the fragmentation of the mole's forest habitat, with people collecting firewood, cutting down trees for building, and introducing livestock.

House shrew
*Suncus murinus*

Good sense of smell and sharp hearing

Piebald shrew
*Diplomesodon pulchellum*

Small eyes with poor vision

Vocalizations include screams and twitters

Feet fringed with hairs to help shrew run across sand

Eurasian common shrew
*Sorex araneus*

Northern short-tailed shrew
*Blarina brevicauda*

Himalayan water shrew
*Chimarrogale himalayica*

Webbed feet for swimming

Elegant water shrew
*Nectogale elegans*

## FACT FILE

**Western European hedgehog** Like other hedgehogs, this species can raise or lower its spines and will protect its head and belly by rolling into a spiky ball. At night, it snuffles through fields, woods, and urban gardens in search of insects, worms, eggs, and carrion

- Up to 10 in (26 cm)
- Up to 1 in (3 cm)
- Up to 3½ lb (1.6 kg)
- Solitary
- Common

N. & W. Europe

## HEDGEHOG HIBERNATION

To cope with the lack of food during cold winters, hedgehogs will go into hibernation, lowering their body temperature and heart and respiration rates to minimize their energy needs. Their metabolic rate can become 100 times slower and they may even stop breathing for up to 2 hours Hibernating hedgehogs live off the extra body fat accumulated in late summer, but also rouse themselves for a day or so every couple of weeks to forage and defecate.

***Getting settled*** *While the Western European hedgehog makes a hasty nest in summer, it takes more care in winter, choosing a well-insulated site*

## FACT FILE

**House shrew** Like the house mouse, the house shrew has flourished living alongside humans. Also known as the money shrew, it makes a jangling sound as it forages for insects in houses

- Up to 6½ in (16 cm)
- Up to 3½ in (9 cm)
- Up to 3 oz (90 g)
- Solitary, [illegible]
- Common

S. & S.E. Asia

**Northern short-tailed shrew** This shrew has adapted to a burrowing lifestyle, with a body shape similar to that of the true moles. It hunts soil dwelling animals, immobilizing larger prey such as voles and mice by injecting venomous saliva when it bites

## FACT FILE

**Russian desman** Once found across Europe, this gregarious species is now restricted to a handful of river basins in Russia. Its soft coat made it a target of trappers, but it is now legally protected.

- Up to 5 in (13 cm)
- Up to 8 in (22 cm)
- Up to 8 oz (228 g)
- Solitary
- Vulnerable

E Europe

**American shrew mole** About the size of a shrew and without the large forelimbs of other moles, this animal is North America's smallest mole. It is also the only mole able to climb bushes.

- Up to 3 in (8 cm)
- Up to 1 in (4 cm)
- Up to 1 oz (11 g)
- Solitary
- Locally common

A North America

### SENSITIVE STARS

An arrangement of fleshy tentacles around its nose helps the star-nosed mole sense small fishes, leeches, snails, and other aquatic prey. When this agile swimmer leaves the water, it usually retreats to its network of tunnels.

- Up to 5 in (13 cm)
- Up to 3 in (8 cm)
- Up to 3 oz (85 g)
- Solitary
- Locally common

E North America

***Perceptive rays*** Each of the star-shaped mole's [illegible] tipped with sensitive, [illegible]

## CONSERVATION WATCH

Of the 428 species of insectivores, 40% are listed on the IUCN Red List, as follows:

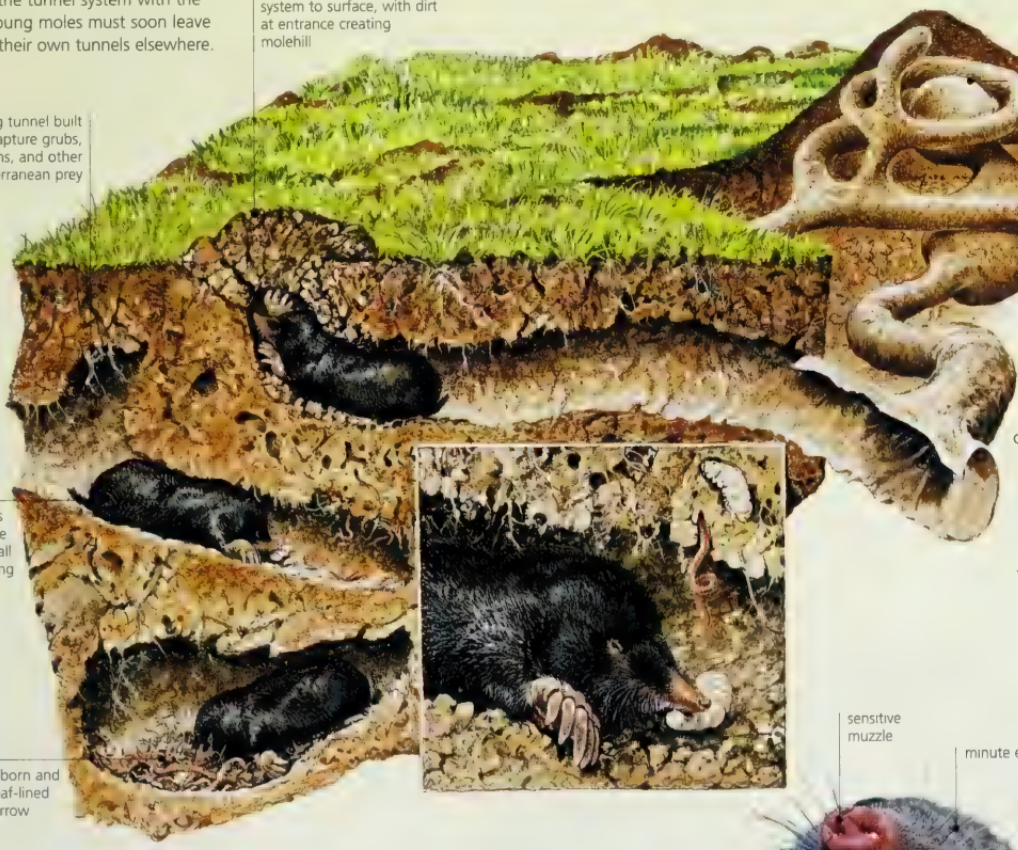
- 5 Extinct
- 36 Critically endangered
- 45 Endangered
- 69 Vulnerable
- 5 Near threatened
- 9 Data deficient

# LIFE BELOW THE SURFACE

Often the only sign of moles in an area is the presence of molehills, small mounds of dirt created when a mole digs a vertical shaft to the surface. Spending almost their entire lives underground, moles dwell in a network of tunnels, sleeping and raising young in a subterranean nest and foraging in the tunnels for earthworms, insect larvae, slugs, and other soil invertebrates. A mole can create up to 65 feet (20 m) of tunnels per day. It usually comes to the surface only to collect grasses and leaf litter to line a nest, or if a stronger animal has evicted it from its home and it needs to find a new territory.

**Raised in the dark** Moles mate in the female's burrow during a frantic breeding season of just 24–48 hours. An average of three young are born a month later, and will be nursed in the nest for a further month. After initially exploring the tunnel system with the mother, young moles must soon leave and build their own tunnels elsewhere.

**Designed to dig** Most moles have enormous, powerful forelimbs with outward-facing hands and spade-like claws. To dig a tunnel, a mole scoops soil sideways and backward, using the smaller hindlimbs to brace itself.




**Tunnel trap** A mole's multitiered tunnel system is made up of central and side tunnels with a single nest chamber. The tunnels operate as a permanent food trap, constantly collecting earthworms and other invertebrate prey as they move through the soil. A mole will swiftly decapitate a trapped earthworm and then pull the prey through its front claws to remove grit and sand. Any surplus worms are kept alive in a cache for use during leaner times

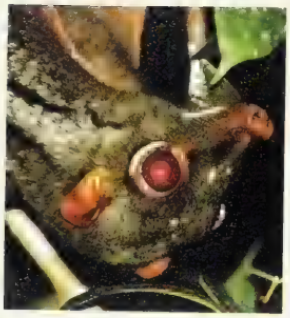
**Subterranean special** A mole's anatomy is highly specialized for an underground life. Muscular shoulders and enlarged forelimbs make it a powerful digger. The dense fur can lie in any direction, allowing the mole to move forward or backward with ease. Virtually hidden by the fur, the tiny eyes do sense changes in light, but can barely see. Instead, the mole relies on touch, with a sensitive, mobile muzzle to seek out food.

# FLYING LEMURS

CLASS Mammalia
ORDER Dermoptera
FAMILY Cynocephalidae
GENUS Cynocephalus
SPECIES 2

Also known as colugos, flying lemurs do not really fly and are not true lemurs. Instead, they glide through the air, and are placed in their own small order, Dermoptera ("skin wing"). These cat-sized animals are helpless on the ground and climb awkwardly in a lurching fashion, but travel easily between the tall trees of their rain-forest home. To minimize the risk of being picked off by a swift bird of prey during a glide, flying lemurs are nocturnal. They spend the day resting, either nestled in tree hollows or clinging to a trunk with their needle-sharp claws. A female flying lemur usually gives birth to a single, rather undeveloped young and then carries it on her belly until it is weaned. Her gliding membrane can be folded to create a snug pouch for the young, and becomes a hammock when she hangs upside down from a branch.

**Narrow distribution** The Malayan flying lemur is found in Malaysia, Thailand, and Indonesia, while the Philippine flying lemur lives only in the Philippines. Both species are hunted by local people for their fur and meat and are threatened by the destruction of their rain-forest habitat



**LEAF-EATER**
A specialized stomach allows flying lemurs to digest the large amounts of leafy vegetation that make up the bulk of their diet. Other foods include buds, flowers, fruit, and possibly tree sap.

Gliding membrane can act as a hammock for the young

Malayan flying lemur
*Cynocephalus variegatus*

**Like a kite** Stretching from the neck to the fingers, toes, and tail, the flying lemur's gliding membrane is the most extensive of any glider. A flying lemur can travel through the air for up to 450 feet (135 m), making an accurate landing with the help of its stereoscopic vision. Four other groups of forest mammals—flying squirrels (*Sciuridae*), scaly-tails (*Anomaluridae*), sugar gliders (*Petauridae*), and the greater glider (*Pseudocheiridae*)—independently evolved with the ability to glide

Ascends tree trunk in a series of hops, clinging to bark with sharp claws

Philippine flying lemur
*Cynocephalus volans*

# TREE SHREWS

**CLASS** Mammalia
**ORDER** Scandentia
**FAMILY** Tupaiidae
**GENERA** 5
**SPECIES** 19

In some Asian tropical forests, small, squirrel-like mammals known as tree shrews scurry along the ground and up trees, foraging for insects, worms, small vertebrates, and fruit. Their sharp claws and splayed toes keep a firm grip on bark and rock alike, while a long tail helps with balance. When eating, they hold food in their hands and may sit on their haunches, alert for predators such as birds of prey, snakes, and mongooses. An average of three young are born in a nest of leaves, which is often made by the father in a tree hollow. Maternal care tends to be limited, with some females visiting only once every 2 days. Considered a primitive form of placental mammal, tree shrews have no direct relationship to true shrews. While a few tree-shrew species spend almost all their time in trees, most are semi-terrestrial and some rarely venture into trees at all.

**Divided family** Tree shrews live in the tropical rain forests of south and Southeast Asia. Initially considered to be insectivores and then grouped with primates, they are now classified in their own order (Scandentia) in a single family (Tupaiidae), which is divided into two subfamilies. The subfamily Ptilocercinae contains just one species, the pen-tailed tree shrew, which is found on Borneo and the Malay Peninsula. The subfamily Tupaiinae contains the other 18 species of tree shrew. The majority of these make their home on the island of Borneo, while the remainder are distributed throughout eastern India and Southeast Asia.

**High fidelity** During their 2- to 3-year life, common tree shrews form a permanent pair and display a high degree of fidelity to their mate. While each partner forages alone by day, the pair shares a territory and will defend it against other members of the species. To advertise ownership, they mark strategic sites and new objects with urine or feces or with a scent produced by glands on the chest and abdomen, rubbing their bodies along branches and other surfaces to deposit the scent. Tree shrews also scentmark their partners and young. If the scent is rubbed off, a female shrew will fail to recognize her offspring and may eat them.

### CONSERVATION WATCH

Of the 19 species of tree shrews, 32% are listed on the IUCN Red List as follows

2 Endangered
4 Vulnerable

# BATS

CLASS Mammalia
ORDER Chiroptera
FAMILY 18
GENERA 177
SPECIES 993

The only mammals with flapping wings and therefore the only ones capable of true flight, bats can travel through the air at speeds of up to 30 miles per hour (50 km/h). This ability has enabled them to cover great distances, exploiting food sources over a wide range and colonizing most parts of the globe, including far-flung islands such as New Zealand and Hawaii, where they are the only native land mammals. Almost 1,000 species of bat form the order Chiroptera, which is the second-largest mammal order. Chiroptera is split into two suborders: the Old World fruit bats, known as Megachiroptera, and the mostly insect-eating New World bats, known as Microchiroptera.

**All over the world** Bats make up nearly one-quarter of all mammal species. While most numerous in warmer regions, bat species are found worldwide except for the polar zones and a few isolated islands Forest bats usually have relatively large, wide wings that offer maneuverability, while bats in open habitats tend to have small, narrow wings, which provide speed

**Mothers' group** As in many bat species, female little bent-winged bats (*Miniopterus australis*) raise young together in nursery colonies. After returning from foraging, the mothers are able to recognize their own offspring among the thousands of young by their cries and odor

**Hanging around** Most bats hang upside down to sleep through the day, a position that allows for a "fast takeoff" while hiding species such as cave-dwelling or burrowing animals, such as the gray-headed flying fox, [illegible] of the [illegible] species

**On the wing** A bat has very long arms and highly modified hands, with all digits except the thumb greatly elongated to support the wing membrane, which is called the patagium. A double layer of skin, the patagium is both flexible and tough

## FLYING FEEDERS

Bats are popularly portrayed as blood-sucking fiends, but only three species of bat drink blood and even these vampire bats display genuine altruism, sharing their food with hungry companions. Most bats are gregarious creatures, with some living in colonies of thousands or even millions of individuals.

More than 70 percent of bats consume insects that fly at night, a source of food exploited by few other animals. In addition to their flying ability, these hunters rely on echolocation, a means of locating both obstacles and prey by emitting high-pitched sounds and detecting the echoes. In many ecosystems, bats play a crucial role in keeping insect populations under control.

Most other bats are herbivores, using a keen sense of smell and effective night vision to locate fruit, flowers, nectar, and pollen. Such bats can be vital for pollination and seed dispersal, and some plants have adapted specifically to attract them, producing large fruits and strongly scented night-blooming flowers.

To minimize their consumption of energy, many bats regulate their body temperature, lowering it when roosting during the day. To cope with the scarcity of food in winter, some temperate species enter longer periods of hibernation, living off body fat deposited in autumn. Others migrate to warmer climes, with one species, the European noctule, flying up to 1,200 miles (2,000 km).

Tufts of hair on shoulders cover glands

Gambian epauletted fruit bat
*Epomophorus gambianus*

Least blossom bat
*Macroglossus minimus*

Uses claws to move through branches

Egyptian fruit bat
*Rousettus aegyptiacus*

Diet includes ripe mangoes, papayas, bananas, and figs

Hammer-headed fruit bat
*Hypsignathus monstrosus*

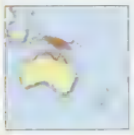
Straw-colored fruit bat
*Eidolon helvum*

Indian flying fox
*Pteropus giganteus*

Eastern tube-nosed bat
*Nyctimene robinsoni*

## FACT FILE

**Least blossom bat** This small bat uses a very long tongue to extract nectar and pollen from the blooms of banana, coconut, and mangrove trees. As the bat travels from feeding site to feeding site, it helps to pollinate the plants



Up to 3 in (7 cm)
Up to ½ in (1 cm)
Up to ¼ oz (18 g)
Solitary pairs
Locally common

N. Australia, New Guinea, some islands

**Egyptian fruit bat** While this species relies mostly on vision, it is one of the few Old World fruit bats with a crude echolocation mechanism, which comes in handy in its dim roosting caves

Up to 5½ in (14 cm)
Up to 1 in (2 cm)
Up to 5½ oz (160 g)
Colonial
Common

Africa & Middle East

**Hammer-headed fruit bat** Males of this large, canopy-roosting species have an enlarged snout and larynx, enabling them to produce loud calls

Up to 12 in (30 cm)
None
Up to 15 oz (420 g)
Colonial, lekking
Locally common

W. & C. Africa

## ALL WRAPPED UP

A roosting Old World fruit bat wraps its wings around its body and holds its head at a right angle to its chest. New World bats tend to fold the wings at the side of the body and hang the head down or at a right angle to the back

## CONSERVATION WATCH

**Bat vulnerability** Because most bats raise just one young per year—a very low reproductive rate for their size—they are especially vulnerable, and populations can [illegible] Fruit bats are tradit[illegible] for food in many [illegible] Asia, and the [illegible] threats include habitat destruction and [illegible]

## FACT FILE

**Yellow-winged bat** Umbrella thorn trees are among this species' favorite roosting sites. When the trees flower, they attract swarms of insects, which are kept in check by the bats

Up to 3 in (8 cm)
None
Up to 1¼ oz (36 g)
Pair, colonial
Locally common

Sub-Saharan Africa

**Greater bulldog bat** This species zig-zags over ponds, rivers, and coastal waters, using echolocation and large, taloned feet to find and capture fish

Up to 5 in (13 cm)
Up to 1½ in (4 cm)
Up to 3 oz (90 g)
Colonial
Locally common

Central & South America, Caribbean

### MAKING A TENT

Rather than hang in a cave or from a branch, the little Honduran tent bat is one of several fruit bats that create their own shelter. It curls a palm frond by chewing through the connection between the leaf's midrib and edges

## CONSERVATION WATCH

Of the 993 species of bats, 52% are listed on the IUCN Red List, as follows:

- 12 Extinct
- 29 Critically endangered
- 37 Endangered
- 173 Vulnerable
- 209 Near threatened
- 61 Data deficient

American false vampire bat
*Vampyrum spectrum*

Greater horseshoe bat
*Rhinolophus ferrumequinum*

Diadem leaf-nosed bat
*Hipposideros diadema*

Bottom part of noseleaf is horseshoe-shaped

Eats small vertebrates but does not target animals for their blood

Hovers at flowers as it collects pollen and nectar with its long tongue

Pallas's long-tongued bat
*Glossophaga soricina*

Complex folds of skin around face

White bat
*Ectophylla alba*

Wrinkle-faced bat
*Centurio senex*

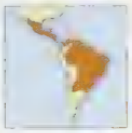
Modified thumbs and strong hindlimbs allow bat to walk, run, and hop on all fours as it hunts terrestrial prey

Common vampire bat
*Desmodus rotundus*

Orange leaf-nosed bat
*Rhinonicteris aurantia*

## FACT FILE

**Common vampire bat** With its razor-sharp teeth, this bat will slice away a small piece of skin from a cow, horse, deer, or other large mammal and lap up the blood. A successful feed usually depends on the prey not noticing the attack, and most young vampires manage to find a meal only two nights out of three. It takes just a few days for a bat to starve to death, so a hungry vampire will beg for food from a roost mate, who will probably oblige by regurgitating blood. Vampire bats are among the few mammal species to display such a degree of generosity.



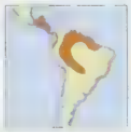
Up to 3½ in (9 cm)
None
Up to 1¼ oz (50 g)
Small to large group
Common

Central & South America

***Vampire fangs***
*The enlarged upper canines and incisors of vampire bats are razor sharp*

## FALSE VAMPIRE DIET

The largest bat in the Americas, the American false vampire hunts birds, other bats, small rodents, reptiles, amphibians, and fish, but does not drink blood. The combination of echolocation and excellent vision makes this bat a powerful predator.



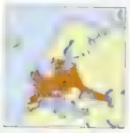
Up to 6½ in (16 cm)
None
Up to 6½ oz (190 g)
Small group
Near threatened

Central & South America

***Feathered food***
*The American false vampire bat consumes vertebrate prey such as parrots*

## FACT FILE

**Western barbastelle** This medium-sized bat roosts in caves, mines, cellars, hollow trees, or under loose bark. It emerges at dusk to search for moths. Although widespread, it appears to be rare almost everywhere in its range.

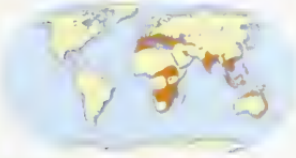


Up to 2½ in (6 cm)
Up to 1½ in (4 cm)
Up to ¼ oz (10 g)
Small group
Vulnerable

W. Europe, Morocco, Canary Islands

**Schreiber's bent-winged bat** In some regions, this species migrates to warmer locations in winter. It roosts by day in caves or buildings, with the young placed in a communal group separate from the adults.

Up to 2½ in (6 cm)
Up to 2½ in (6 cm)
Up to ½ oz (20 g)
Large group
Near threatened



Europe, Africa, S. Asia, Australasia

**Large mouse-eared bat** Consuming up to half its body weight each night, this bat preys on beetles and moths. Groups of 10–100 individuals share roosts in caves and attics. Young are born in April to June and must build up fat to survive the winter hibernation.

Up to 3 in (8 cm)
Up to 2½ in (6 cm)
Up to 1½ oz (45 g)
Small to large group
Near threatened

Europe & Israel

## CONSERVATION WATCH

**Vespertilionid bats** This page shows just a few of the bats in the family Vespertilionidae, the largest, most [illegible]ely distributed bat family, which [illegible]des a species that lives along the arctic treeline. Its members use [illegible] of roosting site, [illegible] Despite this resourcefulness, 2 species are extinct and many depend on conservation efforts, with 7 critically endangered, 20 endangered, and 52 vulnerable species. Even Britain's most abundant bats, the pipistrelles, have declined by more than 6[illegible]

Hoary bat
*Lasiurus cinereus*

Brazilian free-tailed bat
(Mexican free-tailed bat)
*Tadarida brasiliensis*

Swarm of Brazilian free-tailed bats emerging from cave at dusk to feed

White tinge to brown-gray fur creates frosted appearance

White patches on shoulders and rump

Spotted bat
*Euderma maculatum*

European free-tailed bat
*Tadarida teniotis*

Thick tail extends beyond wing membrane

Smallest of all bat species, about the size of a large bumblebee

Hog-nosed bat
*Craseonycteris thonglongyai*

Pocketed free-tailed bat
*Nyctinomops femorosaccus*

Thick, leathery wings can be rolled away, freeing up forelimbs for walking on the ground

Sucker-footed bat
*Myzopoda aurita*

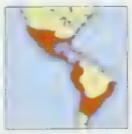
Roosts with head above body

Suction cups on wrists and ankles

New Zealand lesser short-tailed bat
*Mystacina tuberculata*

## FACT FILE

**Brazilian free-tailed bat** Many bat species roost communally, but Brazilian free-tailed bats hold the record for the largest gathering, with over 20 million sharing Bracken Cave, Texas, United States. Every evening, a spectacular swarm of bats emerges from the cave in search of food. It is estimated that they consume more than 250 tons (225 t) of insects per night. Many members of this species migrate from Mexico to Texas every spring to breed, returning south in autumn.



Up to 3 in (7 cm)
Up to 1½ in (4 cm)
Up to ½ oz (15 g)
Colonial
Near threatened

North & South America, Caribbean

**Sucker-footed bat** Now found only on the island of Madagascar, this little bat uses the suction cups on its wrists and ankles to cling to leaves, supported by its long tail. The disk-winged bats (genus *Thyroptera*) of Central and South America also have suction cups at the end of their limbs. This adaptation appears to have evolved independently in the Old and New World species.

Up to 2½ in (6 cm)
Up to 2 in (5 cm)
Up ¼ oz (10 g)
Not known
Vulnerable

E. & N. Madagascar

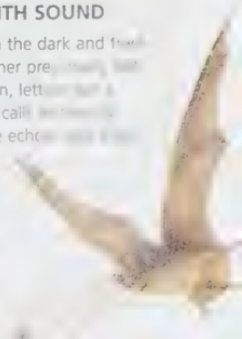
**New Zealand lesser short-tailed bat** Along with a larger bat species that became extinct early last century, these bats are New Zealand's only native land mammals. Descended from relatives of South American sheath-tailed bats, they forage on the ground and on tree trunks, flying only when necessary.

Up to 3 in (7 cm)
Up to ½ in (1 cm)
Up to ½ oz (15 g)
Colonial
Vulnerable

New Zealand

### SEEING WITH SOUND

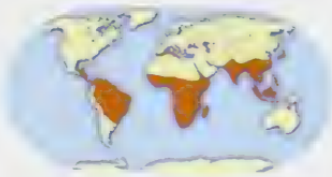
To find their way in the dark and tracking down insects or other prey, bats rely on echolocation, letting out a series of ultrasonic calls. The strength of the echoes tells them about the distance of an obstacle or prey, while slight differences in the delay reveal the direction



# PRIMATES

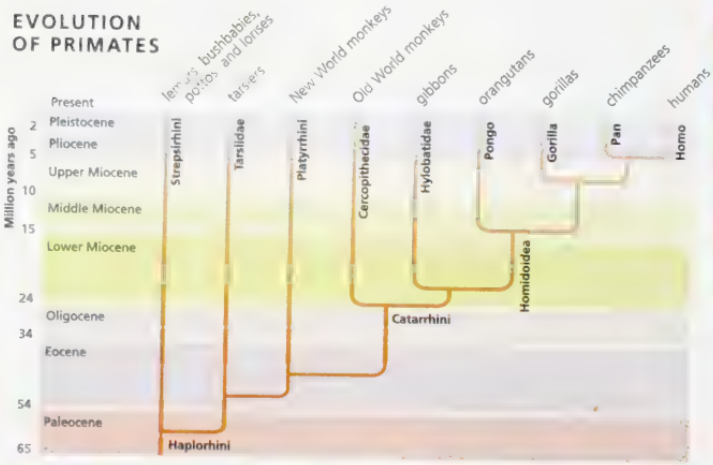
CLASS Mammalia
ORDER Primates
FAMILIES 13
GENERA 60
SPECIES 295

Charismatic and intelligent, lemurs, monkeys, apes, and their close relatives make up the order known as Primates. Early primates were tree-dwellers and developed adaptations for an arboreal lifestyle: forward-facing eyes with stereoscopic vision to help judge distances when traveling through the trees; dextrous hands and feet to firmly grasp branches; and long, flexible limbs to enhance agility when foraging. Most primates are still largely arboreal, but even those that have opted for life on the ground retain at least some of these adaptations. Perhaps the most fascinating aspect of this order is the complex social behavior displayed by many species.

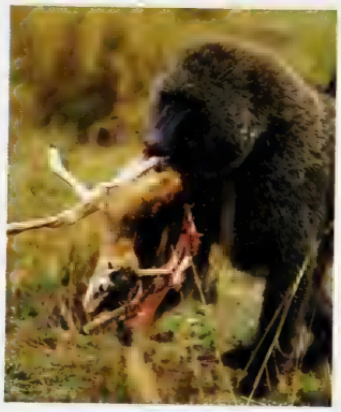


**Tropical distribution** Although most primates live in the tropical rain forests between 25°N and 30°S, a handful of species are found farther afield, in North Africa, China, and Japan

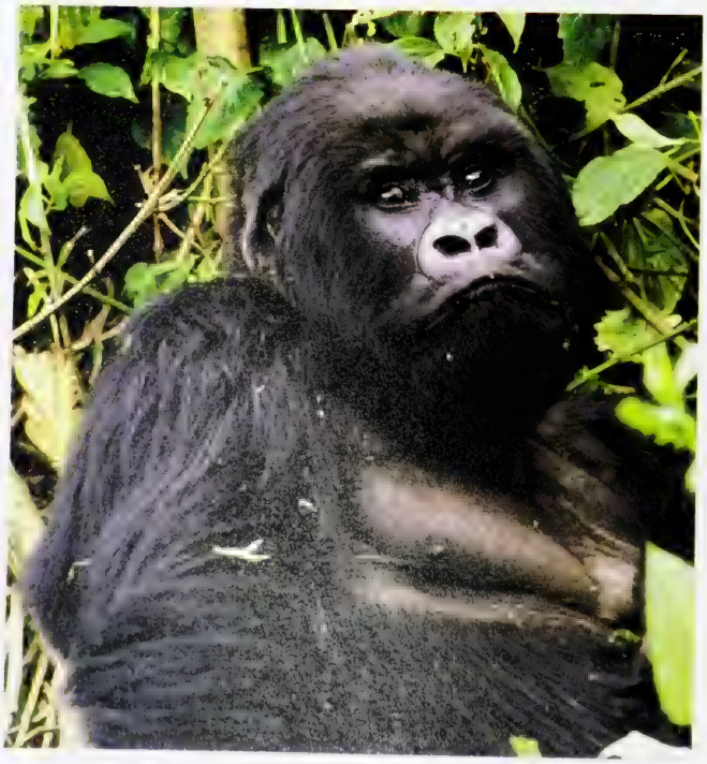
## EVOLUTION OF PRIMATES



**Strepsirhine primate** Like other members of the suborder Strepsirhini, the Coquerel's dwarf lemur is distinguished by a moist, pointed snout and a keen sense of smell. Nocturnal and solitary, this small primate forages for flowers, fruit, and insects.



**Meat eater** For most primates, leaves, fruit, and insects make up the bulk of the diet, but baboons, chimpanzees, and humans also hunt large vertebrates. Here, an olive baboon (*Papio hamadryas anubis*) returns with its kill of a young gazelle



**Haplorhine primate** Along with monkeys and humans, the gorillas and other apes make up the suborder Haplorhini. Gorillas are social animals, living in troops of one or two silverback males, a few younger males, and several females and young

## PRIMATE DIVERSITY

While some small primates are solitary foragers, relying on hiding and nocturnal habits to escape predators, many larger primates are active by day and form groups as protection. A group offers many pairs of eyes to watch for predators. Even when a predator does attack, there is a good chance that it will take another member of the group. Some primates will fight off an attack together—baboons have been known to kill an attacking leopard.

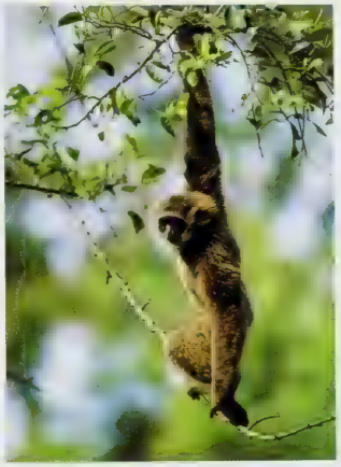
The size and organization of primate groups vary enormously. Some species live in monogamous pairs, while others form troops of several females and one or more males. Stable troops of 150 geladas sometimes combine into herds of 600 individuals. The most common structure is based on related females and their offspring, often headed by a single male. Group living leads to greater competition for food and mates, which is negotiated through complex hierarchies and alliances. These elaborate social networks rely on precise communication, with many species employing a range of nuanced visual and vocal signals. Relative to body size, primates have much larger brains than most other mammals, a feature that may be linked to their complex social lives.

The life of a primate moves slowly. Gestation periods are long; birth rates are low, with just one or two young in a litter; growth rates are slow, with long periods of dependency as infants and juveniles; and lifespans are long. This may be the cost of the large primate brain, which uses energy that would otherwise be available for growth and reproduction.

Primates range from the pygmy mouse lemur (*Microcebus myoxinus*), at 4 inches (10 cm) long and 1 ounce (30 g) in weight, to the gorilla, standing more than 5 feet (1.5 m) high and weighing 400 pounds

**Temperate life** Japanese macaques are among the few primates to live outside the tropics and subtropics. During the cold, snowy winters, their furry coats thicken and they feed on bark, buds, and stored food reserves, and warm up in thermal pools.

**Vertical posture** Chimpanzees and other apes sit and sometimes walk upright, supported by a shorter back, broader rib-cage, and stronger pelvis than those of monkeys and lemurs. The arms, often used in locomotion, are longer than the legs, and the wrists are highly flexible.



**Swinging through the trees** Gibbons use their extremely long arms to swing from tree to tree, a form of movement known as brachiation. They rely on stereoscopic vision to accurately judge the distance of their next handhold.

(180 kg). Many small primates feed primarily on insects, a quickly processed food source to fuel their fast metabolisms. Larger species need greater volumes of food and often concentrate on leaves, shoots, and fruit, which are slow to digest but are in abundant supply. The general reliance on fruit, shoots, leaves, and insects has probably helped restrict primates largely to the tropics, where these foods are available year round.

The order Primates is split into two suborders: Strepsirhini, made up of lemurs and their relatives, and Haplorhini, comprised of tarsiers, monkeys, apes, and humans. Tarsiers and strepsirhines share a number of primitive features and have been collectively referred to as prosimians.

**Busy social lives** The large brains of primates such as baboons may be needed to manage the complex social relationships associated with living in a hierarchical group. While group living leads to greater competition for food, it reduces the risk of being attacked by predators.

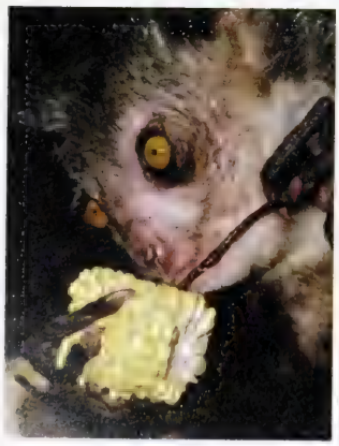
**Primate survival** About a third of all primate species are at risk of extinction, victims of habitat loss and hunting. Large species such as the orangutan are especially vulnerable as they are easy for hunters to find

# PROSIMIANS

CLASS Mammalia
ORDER Primates
FAMILIES 8
GENERA 22
SPECIES 63

The name *prosimians* means "before monkeys," a reference to the fact that these creatures retain many features of the early primates. Absent from the Americas, prosimians include the lemurs of Madagascar, the bushbabies and pottos of Africa, and the lorises of Asia—all members of the suborder Strepsirhini. These species all possess a moist, pointed snout and most have a light-reflecting disk in the eye, a long toilet claw, and compressed lower teeth forming a dental comb. Tarsiers, now classified in the suborder Haplorhini, are also often referred to as prosimians because their appearance and solitary, nocturnal behavior is like that of many strepsirhines.

**Arboreal attitude** Like other prosimians, the slender loris is superbly adapted for a life in trees. Its large, forward-facing eyes provide stereoscopic vision to accurately judge distances, while its dextrous hands and feet keep a firm grip on the branches



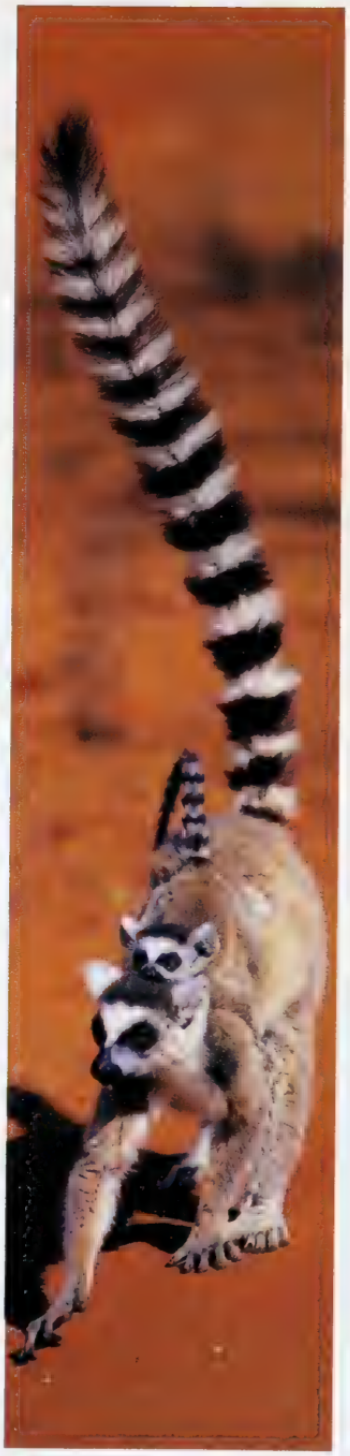
**Getting grubby** [illegible]

## SPECIALIZED SENSES

Prosimians tend to be relatively small, nocturnal tree-dwellers who forage alone but may occasionally form limited groups. Most are largely insectivorous but will also consume fruit, leaves, flowers, nectar, and gum. They display two specializations for grooming: a long claw on the second toe of the foot, known as the toilet claw; and the dental comb, a compressed row of protruding lower teeth. The dental comb also seems to be used for scraping resin off trees.

The moist, dog-like snout shared by lemurs, lorises, and the other strepsirhines supplies them with a wealth of information through smell. Sight is also important, but they do not have the full color vision of monkeys and apes. Sophisticated color vision would be of limited use to creatures that forage in the low-light conditions of night. Instead, most prosimians have a tapetum lucidum, a crystalline layer behind the retina that reflects light and produces the characteristic eyeshine of many nocturnal mammals.

While sound is important in prosimian communication, with many species employing alarm and territorial calls, scent plays a major role. Territories are often marked with urine, feces, or secretions from special scent glands, which can convey an individual's sex, identity, and breeding status.



**Terrestrial troops** Unusually among prosimians, ring-tailed lemurs are active during the day and spend most of their time on the ground. Their troops of between 3 and 20 animals are dominated by female lemurs, a matriarchal structure found in few other primates. Females give birth to one or two young, whose care is shared by the troop

Broad-nosed gentle lemur
*Hapalemur simus*

Mongoose lemur
*Eulemur mongoz*

Ring-tailed lemur
*Lemur catta*

Large forward-facing eyes

Black lemur
*Eulemur macaco*

Brown lemur
*Eulemur fulvus*

Coquerel's dwarf lemur
*Microcebus coquereli*

Long tail can store fat reserves

Characteristic forked stripe on head

Fork-marked lemur
*Phaner furcifer*

## FACT FILE

**Broad-nosed gentle lemur** More than 95 percent of this lemur's diet is made up of bamboo shoots, leaves, and stalks. One of the world's rarest mammals, it was not seen for a century and was considered extinct until its rediscovery in 1972

Up to 17½ in (45 cm)
Up to 22 in (56 cm)
Up to 5½ lb (2.5 kg)
Family band
Critically endangered

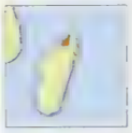
S.E. Madagascar

**Mongoose lemur** Usually nocturnal during the dry season, mongoose lemurs switch to daytime activity for the colder wet season. They live in small groups made up of a male and female pair and their offspring

Up to 17½ in (45 cm)
Up to 25 in (64 cm)
Up to 6½ lb (3 kg)
Family band
Vulnerable

N.W. Madagascar (S. of Narinda Bay), Comoro I

**Black lemur** For years, male and female black lemurs were considered different species because they look so unalike. Males are black, but females are chestnut-brown with white bellies and ear tufts. This tree-dwelling species feeds on fruit, flowers, and nectar.

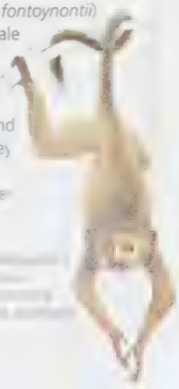


Up to 17½ in (45 cm)
Up to 25 in (64 cm)
Up to 6½ lb (3 kg)
Family band
Vulnerable

N.W. Madagascar (N. of Narinda Bay)

## LEMURS OF MADAGASCAR

For millions of years, lemurs have been isolated on the island of Madagascar, where they have adapted to a variety of forest niches and developed the remarkable diversity evident today. They now range from the size of a mouse to that of a medium domestic dog, but the recently extinct giant sloth lemur (*Archaeoindris fontoynontii*) was bigger than a male gorilla. Most lemurs are arboreal and nocturnal, but some live on the ground and are active by day. They can be solitary, live in pairs, or form large permanent troops.



***Habitat loss***

## HANDS AND FEET

The contrasting lifestyles of primates are evident in the shape of their hands and feet. The indri and the tarsier cling vertically and leap from tree to tree, while the aye-aye climbs through the branches. The gorilla can climb but spends most of its time on the ground.

***Clinging indri***
The indri's stout thumb and big toe help it to cling firmly to tree trunks.

***Digging aye-aye***
Rather than clinging, the aye-aye climbs by digging its long claws into the bark.

***Tarsier friction***
A tarsier's grip is strengthened by the friction of the disk-like pads on its fingers and toes.

***Broad-handed gorilla***
Large primates, gorillas have broad hands and feet to help support their great weight.

## CONSERVATION WATCH

Of the 63 species of prosimians, 76% are listed on the IUCN Red List, as follows

- 3 Critically endangered
- 8 Endangered
- 12 Vulnerable
- 17 Near threatened
- 8 Data deficient

Woolly lemur
*Avahi laniger*

Thick, woolly coat

Large, black, tufted ears

Indri
*Indri indri*

Furless black face

Verreaux's sifaka
*Propithecus verreauxi*

Only lemur with a very short tail

Diadem sifaka
*Propithecus diadema*

Almost completely arboreal

## FACT FILE

**Woolly lemur** The ascending alarm call of this species sounds like "Ava Hy," inspiring the genus name of *Avahi*. Family groups, made up of a breeding pair and their young, spend the day sleeping together among vines.

Up to 17½ in (45 cm)
Up to 16 in (40 cm)
Up to 2½ lb (1.2 kg)
Pair
Near threatened

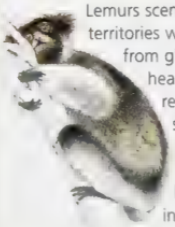
E. Madagascar

**Indri** The largest surviving lemur, the indri is active by day, leaping from tree to tree in search of fruit and flowers. It announces its presence with loud wailing calls and marks territory using scent glands in its cheeks.

Up to 35½ in (90 cm)
Up to 2 in (5 cm)
Up to 22 lb (10 kg)
Family band
Endangered

N.E. Madagascar

## LEAVING A TRACE



Lemurs scentmark their territories with secretions from glands on the head, hands, or rear. The indri's scent glands are in its cheeks, while the woolly lemur has them in its neck.

## CLING AND LEAP

The indri, sifakas, and woolly lemurs are all vertical clingers and leapers. They remain upright as they travel from tree to tree, propelled for up to 30 feet (10 m) by their long, powerful legs. On the rare occasions that these lemurs descend to the ground, they jump about on their legs, holding their arms above the head for balance.

***Sifaka on the move***
*On the ground, Verreaux's sifaka hops sideways, with arms raised. Tucked into the chest, the arms may take on the pose of a boxer.*

## FACT FILE

**Lesser bushbaby** This nocturnal animal prefers to feed on grasshoppers and other insect prey. When insects become rare during times of drought, it will feed solely on acacia gum, allowing it to survive in drier habitats

- Up to 8 in (20 cm)
- Up to 12 in (30 cm)
- Up to 10½ oz (300 g)
- Family band
- Common

E. & S. Africa

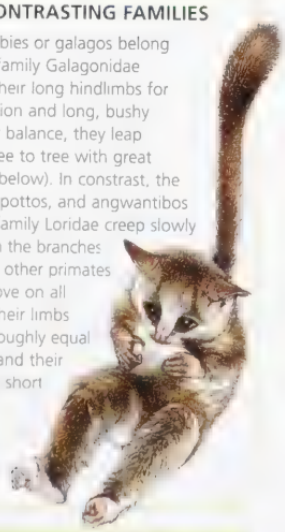
**Demidoff's galago** By day, Demidoff's galago sleeps in an elaborate spherical nest of leaves. One of the smallest primates, it has a fast metabolism and requires an energy-rich diet, 70 percent of which is made up of insects

- Up to 6 in (15 cm)
- Up to 8½ in (21 cm)
- Up to 4 oz (120 g)
- Family band
- Locally common

C. Africa

### CONTRASTING FAMILIES

Bushbabies or galagos belong to the family Galagonidae. Using their long hindlimbs for propulsion and long, bushy tails for balance, they leap from tree to tree with great agility (below). In constrast, the lorises, pottos, and angwantibos of the family Loridae creep slowly through the branches. As with other primates that move on all fours, their limbs are of roughly equal length and their tails are short



## CONSERVATION WATCH

**Bushbaby threats** While only one bushbaby species, the Rondo dwarf galago (*Galago rondoensis*), is listed as endangered, six others are near threatened. Of the remainder, many have not been studied enough for an accurate assessment of their status to be made. Several species were identified only in recent years and it is likely that more remain to be discovered. Meanwhile, their tropical forest habitat is being rapidly degraded and fragmented by logging and farming

Naked tail tipped with tuft of hair

Slender loris
*Loris tardigradus*

Eyes cannot move but head can rotate almost a full circle

Climbs on all fours with slender limbs of equal length

Western tarsier
*Tarsius bancanus*

Angwantibo (golden potto)
*Arctocebus calabarensis*

Potto
*Perodicticus potto*

Moves slowly through branches on all fours

Spectral tarsier
*Tarsius spectrum*

Very long, skinny digits for grasping branches

Slow loris
*Nycticebus coucang*

## FACT FILE

**Potto** This animal attempts to avoid detection by moving very slowly and freezing in place for hours if necessary. Its hands and feet have areas for blood storage that allows them to maintain their hold without muscle fatigue. When confronted by a predator, the potto adopts a defensive posture but will bite if attacked.

- Up to 17½ in (45 cm)
- Up to 4 in (10 cm)
- Up to 3½ lb (1.5 kg)
- Solitary
- Locally common

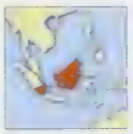
C. Africa

***Defense position*** *A threatened potto tucks its head down and presents its neck, which has a shield of spiny vertebrae covered by horny skin.*

## TARSIERS

Tarsiers are properly classified in the suborder Haplorhini with the monkeys and apes. They lack the wet snout shared by the strepsirhines, but do bear many superficial resemblances to this group. With their long legs, slender fingers and toes, large ears, and enormous eyes, they look much like a bushbaby with a thin tail. The only carnivorous primates, tarsiers can turn their head almost 360 degrees as they search for prey such as insects, lizards, snakes, birds, and bats.

**Western tarsier** Like other tarsiers, this nocturnal species lacks a light-reflecting disk to enhance its night vision, but it does have incredibly large eyes. Each eye is bigger than its brain.



- Up to 6 in (15 cm)
- Up to 10½ in (27 cm)
- Up to 6 oz (165 g)
- Solitary
- Data deficient

Sumatra, Borneo, Bangka, Belitung, Serasan

**Spectral tarsier** Pushing off with its very long legs, this small primate can leap up to 20 feet (6 m) between tre[illegible] On the ground, it moves about b[illegible] hopping on its back legs.

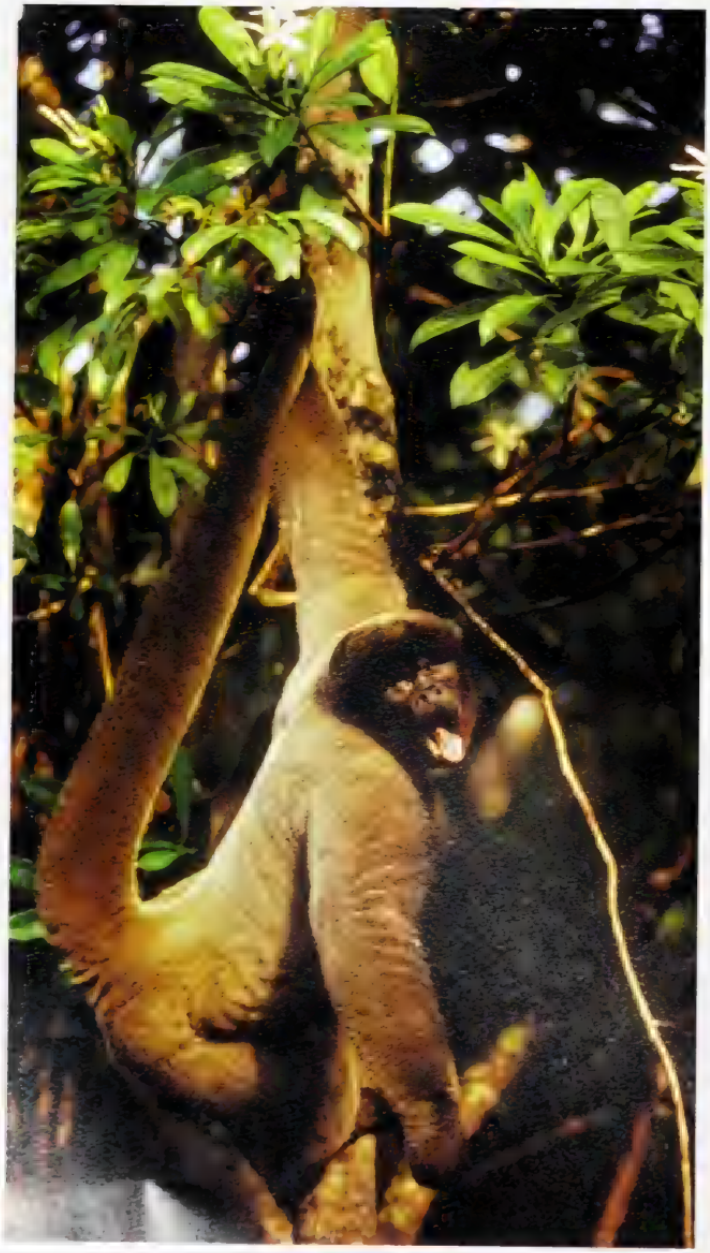
Sulawesi, Sangihe, Peleng, Salayar

# MONKEYS

CLASS Mammalia
ORDER Primates
FAMILIES 3
GENERA 33
SPECIES 214

Geography has determined two separate lineages of monkeys: the New World monkeys of the Americas, classified within the suborder Haplorhini as platyrrhines; and the Old World monkeys of Africa and Asia, grouped with apes and humans as catarrhines. New and Old World monkeys are most easily distinguished by the shape of their noses and by the arrangement of their teeth. All New World monkeys live in trees and many have strong prehensile tails to grip branches. While most Old World monkeys are also arboreal, none has a prehensile tail and some species are semi-terrestrial. Some Old World monkeys have callous pads on their rumps, a feature found on no New World species.

***Old and new*** Old World monkeys (above) have prominent noses with narrow, forward-facing nostrils. The noses of New World monkeys (right) are flattened, with nostrils facing sideways.



**Treetop life** South America's gray woolly monkey (Lagothrix cana) is superbly adapted for an arboreal lifestyle. It swings through the trees, aided by muscular shoulders and hips, long, strong limbs, and grasping hands and feet. The prehensile tail acts as a fifth limb and features a bare gripping pad on the underside near the tip.

**Pulling rank** Many baboons live in large multi-male troops, and males will fight furiously to establish their dominance and gain access to the females. A troop's rank order, decided by both fighting and alliances, is not permanent, changing as the dominant male grows older or as males join or leave the troop.

## SOCIAL SIMIANS

Monkeys tend to be medium-sized, ranging from the pygmy marmoset, with a length of 6 inches (15 cm) and a weight of 5 ounces (140 g), to the mandrill, measuring 30 inches (76 cm) long and weighing in at 55 pounds (25 kg). Most live in social groups, are active by day, and eat mainly fruit and leaves. All Old World monkeys and many New World monkeys have developed full color vision, which allows them to easily spot fruit among the foliage.

Like apes, monkeys differ from lemurs and other strepsirhines by having a less slightly hairy muzzle, a greater dependence on sight over smell, and a larger brain relative to body size. Not only are the brains of monkeys and apes larger, but the neocortex, the brain's outer sheath, is especially well developed. The neocortex is associated with creative thinking, an advantage when dealing with the machinations of group life. Monkeys are known to deliberately deceive other members of their group, raising false alarm calls, for example, in order to distract them from a source of food.

The social arrangements of monkeys display great variety: small family groups may contain just one monogamous breeding pair and their offspring, harems of several females may be dominated by a single adult male, and large troops may include several adult males and many females. While large groups often involve fierce competition to establish rank, they also feature extensive cooperation. Relationships among monkeys tend to be close and enduring, cemented by regular episodes of mutual grooming.

Golden lion tamarin
*Leontopithecus rosalia*

Striking reddish-gold coat with long mane framing black face

Pygmy marmoset
*Callithrix pygmaea*

Claws on all digits except big toe, which has a flat nail

Golden-headed lion tamarin
*Leontopithecus chrysomelas*

White ear tufts on adults and juveniles, absent from infants

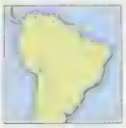
Cotton-top tamarin
*Saguinus oedipus*

Geoffroy's tamarin
*Saguinus geoffroyi*

Common marmoset
*Callithrix jacchus*

## FACT FILE

**Golden lion tamarin** There are only about 800 golden lion tamarins left in the wild. Their striking appearance made them popular pets and zoo exhibits, with many falling victim to the live-animal trade until it became illegal in the 1970s. Deforestation continues to have a serious impact



Up to 11 in (28 cm)
Up to 16 in (40 cm)
Up to 1½ lb (650 g)
Family band
Endangered

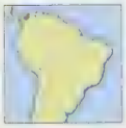
Coastal forest in Brazil

**Pygmy marmoset** The smallest of the world's monkeys, this species gouges out holes in trees to release its favorite food of sap and gum. It runs on all fours along branches, leaping from tree to tree. Group members use high-pitched trillings to communicate.

Up to 6 in (15 cm)
Up to 8½ in (22 cm)
Up to 5 oz (140 g)
Family band
Locally common

W Amazon basin

**Cotton-top tamarin** After spending the night resting in the forks of their sleeping tree, a group of 3–9 cotton-top tamarins will move through the trees of the canopy searching for insects, fruit, and gum.



Up to 10 in (25 cm)
Up to 16 in (40 cm)
Up to 1 lb (500 g)
Family band
Endangered

N. Colombia

## COOPERATIVE BREEDING

Marmosets and tamarins usually live in small groups of several unrelated adult males and females. There tends to be only one breeding female, who often mates with more than one male and gives birth to twins. Uniquely among primates, the young are then cared for by all members of the group, including the unrelated males

***Babysitting duties*** *A male Geoffroy's tamarin will carry the young of a female [illegible]*

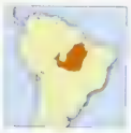
## FACT FILE

**Northern night monkey** The world's only nocturnal monkeys, night monkeys use their acute sense of smell and large eyes to find insects, fruit, nectar, and leaves in low light. They live in monogamous pairs, with the male responsible for the bulk of infant care

- Up to 18½ in (47 cm)
- Up to 16 in (41 cm)
- Up to 2½ lb (1.2 kg)
- Pair
- Common

C. Venezuela, N. W. Brazil

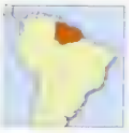
**Dusky titi** Titi monkeys live in closely bonded family groups, and a pair will often sit side by side with their tails entwined. They are active by day, when they consume large amounts of fruit



- Up to 14 in (36 cm)
- Up to 18 in (46 cm)
- Up to 3 lb (1.4 kg)
- Family band
- Locally common

C. Amazon basin

**White-faced saki** The long hindlimbs of these active tree-dwellers enable them to leap up to 30 feet (10 m) between trees. At night, they sleep curled up on branches like cats



- Up to 19 in (48 cm)
- Up to 17½ in (45 cm)
- Up to 5½ lb (2.4 kg)
- Family band
- Uncommon

Guianas, Venezuela, N. Brazil

**Black-headed uakari** This species lives in groups of up to 50 individuals, which include more than one adult male. Adult females and young engage in social grooming. For a tree-dweller, the uakari has an unusually short tail

- Up to 19 in (50 cm)
- Up to 8½ in (21 cm)
- Up to 9 lb (4 kg)
- Large troop
- Rare

Upper Amazon basin

## CONSERVATION WATCH

Of the 214 species of monkeys, 56% are listed on the IUCN Red List, as follows:

- 14 Critically endangered
- 32 Endangered
- 32 Vulnerable
- 7 Conservation dependent
- 26 Near threatened
- 11 Data deficient

Black howler
*Alouatta caraya*

Males are black, females are brown or olive, and infants are golden

Prehensile tail grips branches

Common squirrel monkey
*Saimiri sciureus*

Mantled howler
*Alouatta palliata*

Red howler
*Alouatta seniculus*

White-fronted capuchin
*Cebus albifrons*

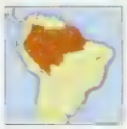
Brown capuchin
*Cebus apella*

Weeping capuchin
*Cebus olivaceus*

White-throated capuchin
*Cebus capucinus*

## FACT FILE

**Common squirrel monkey** These agile monkeys live in large troops of 50 or more. Unlike most other monkeys, they are seasonal breeders, mating promiscuously within their own group between September and November. Young are born between February and April, the wettest part of the year when food is most abundant



Up to 12½ in (32 cm)
Up to 17 in (43 cm)
Up to 3 lb (1.4 kg)
Large troop, herd
Common

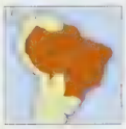
Amazon basin, Guianas

**Red howler** The red howler is the largest of the nine howler monkey species. Howlers have a very deep jawbone to help chew the leaves that make up most of their diet, and an enormous gut to help digest them

Up to 27 in (69 cm)
Up to 31 in (79 cm)
Up to 24½ lb (11 kg)
Family band
Locally common

Venezuela to upper Amazon basin

**Brown capuchin** Troops of a dozen or so brown capuchins forage together by day, led by a dominant male who has first pick of the food. These monkeys sometimes use simple tools, cracking open a nut with a stone, for example



Up to 19 in (48 cm)
Up to 19 in (48 cm)
Up to 10 lb (4.5 kg)
Small troop
Locally common

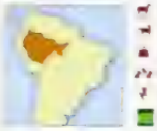
N.E. South America

### HOWLING

One of the loudest calls in the animal world is made by howler monkeys. At dawn, howler troops announce their presence with a deafening conversation of howls that resonate through the forest, traveling up to 3 miles (5 km) away. By helping troops avoid one another, the howls prevent territorial skirmishes that would waste time and energy that could be better spent eating or resting

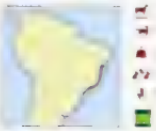
## FACT FILE

**Common woolly monkey** [illegible]



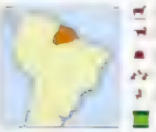
[illegible]

**Woolly spider monkey** [illegible]



[illegible]

**Black spider monkey** [illegible]



[illegible]

## TREETOP ANATOMY

[illegible]

Capped leaf monkey
*Trachypithecus pileatus*

Hanuman langur
*Semnopithecus entellus*

Douc langur
*Pygathrix nemaeus*

Male's pendulous nose adds resonance to calls

Chinese snub-nosed monkey
*Rhinopithecus roxellana*

Slight webbing between digits helps to make proboscis monkey an excellent swimmer

Proboscis monkey
*Nasalis larvatus*

## FACT FILE

**Proboscis monkey** [illegible] named after the pendulous nose of the male. It lives in social hierarchies, one adult male and several females. Sexual ornament is restricted to the female, who indicates her readiness to conceive by posing her gap. If the male rejects her gaze, she ingests her feces. The male then mounts her posing expression and she presents her hindquarters to him. During copulation, both male and female proboscis monkeys mumble in pouting expression and the female keeps rapidly moving her head.

## INFANTICIDE

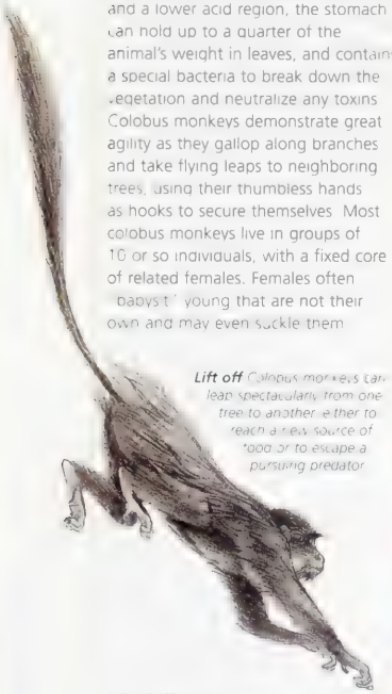
Although most thoroughly studied among Hanuman langurs, infanticide is practiced by many primates. In langurs, a new male becomes dominant in a group, often after a previously hard fought contest. The new male kills all the group's unweaned infants, presumably because females preventing the mothers from conceiving. Although the mothers often try to defend their young, their efforts usually unsuccessful. With their infants dead, the females stop lactating and are able to conceive the offspring of the newly dominant male.

**Competition and cooperation** [illegible]

**Rival males** [illegible]

## COLOBUS MONKEYS

Like the langurs of Asia, the colobus monkeys of Africa have a specialized stomach that has allowed them to exploit the most reliable food source in their forest habitat. Divided into a very large, chambered upper region and a lower acid region, the stomach can hold up to a quarter of the animal's weight in leaves, and contains a special bacteria to break down the vegetation and neutralize any toxins. Colobus monkeys demonstrate great agility as they gallop along branches and take flying leaps to neighboring trees, using their thumbless hands as hooks to secure themselves. Most colobus monkeys live in groups of 10 or so individuals, with a fixed core of related females. Females often "babysit" young that are not their own and may even suckle them.



***Lift off*** *Colobus monkeys can leap spectacularly from one tree to another, either to reach a new source of food or to escape a pursuing predator.*

***Mixed alliances***
*Colobus monkeys often form temporary or even stable associations with other monkey species. Red colobus monkeys and vervets, for example, may cooperate during the dangerous activity of drinking from a water hole, taking turns to keep an eye out for predators.*

### CONSERVATION WATCH

**Disappearing red colobus** All eight subspecies of red colobus are classified as endangered or critically endangered. Another subspecies, Miss Waldron's red colobus monkey (*Procolobus badius waldroni*), was declared extinct in 2000, the first documented extinction of a primate since 1900. Hunted for meat, red colobus monkeys make easy targets because they are brightly colored and vocal. They are also rapidly losing much of their forest habitat to logging, road building, and farming.

## FACT FILE

**Rhesus macaque** Up to 200 of these gregarious monkeys live together in a group. Adapted to a wide range of habitats, they vary their diet according to season and location, with some in urban areas raiding gardens and trash cans. The species has been extensively used in medical research.

Up to 25½ in (65 cm)
Up to 12 in (30 cm)
Up to 22 lb (10 kg)
Large band
Near threatened

Afghanistan & India to China

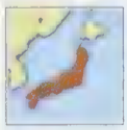
**Barbary ape** This species lives in multi-male troops of up to 40 animals who maintain a home range. Females mate with all males in the troop. Each male chooses a single infant to help raise, but this may not be his own offspring.

Up to 27½ in (70 cm)
None
Up to 22 lb (10 kg)
Variable
Vulnerable

N. Morocco, N. Algeria; introd. Gibraltar

## SNOW MONKEYS

Japanese macaques live farther north than any other primate (apart from humans). During the cold, snowy winters, they live off tree buds and bark, as well as stores of fat. Troops of 20–30 Japanese macaques are headed by a dominant male. Their social lives tend to be harmonious, with much time spent grooming each other and sharing the care of the young.



Up to 23½ in (60 cm)
Up to 6 in (15 cm)
Up to 22 lb (10 kg)
Variable
Data deficient

Japan

***Making snowballs*** *Entire troops of Japanese macaques make snowballs, fash[illegible] a small ball in [illegible] hands then rolling it along the ground so it grows in siz[illegible]*

## FACT FILE

**Hamadryas baboon** At night, troops of up to 750 of these baboons sleep together on rocky outcrops, splitting into bands of 20–70 animals at dawn to forage for grass, fruit, leaves, flowers, and small vertebrates. These bands are made up of harem families—a single dominant male, with several females, and their juvenile offspring.

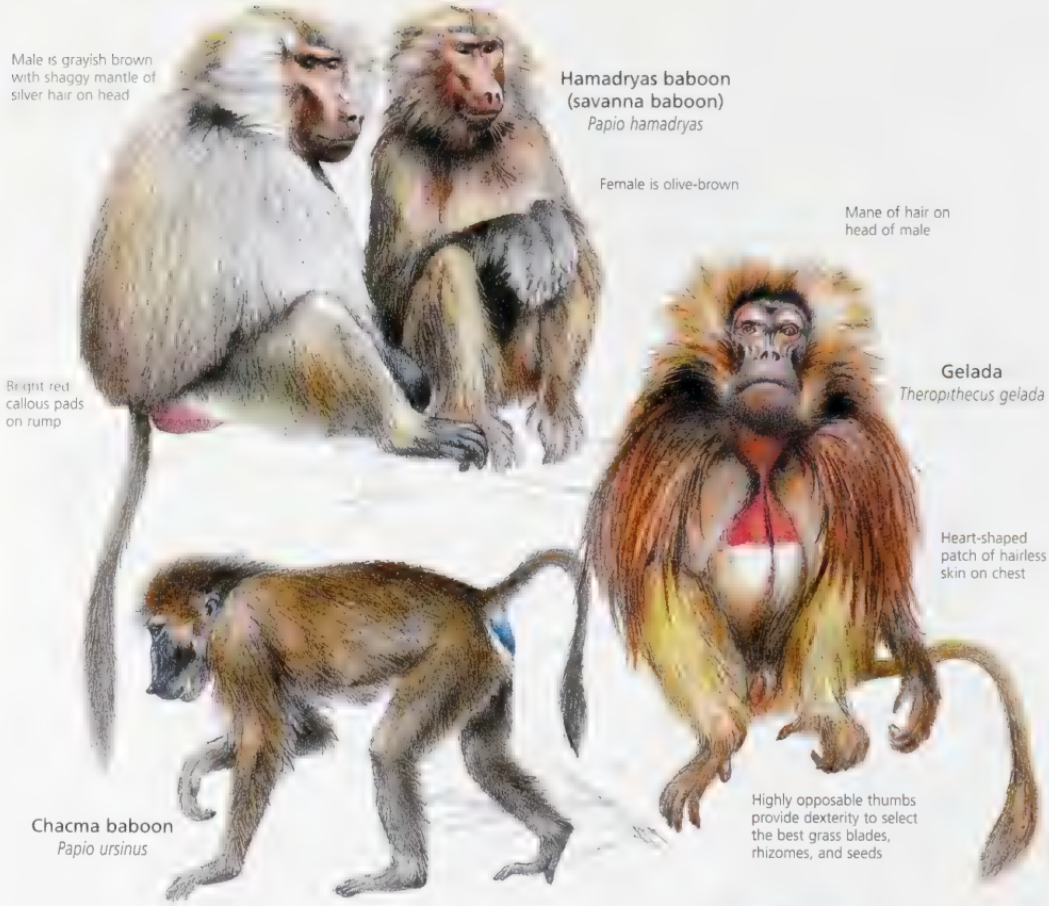
- Up to 35½ in (90 cm)
- Up to 27½ in (70 cm)
- Up to 44 lb (20 kg)
- Family band, troop
- Near threatened

Ethiopia, Somalia, Eritrea, Sudan, Arabian P

**Chacma baboon** This species lives in a variety of habitats, including the most arid environments inhabited by any primate other than humans. One troop of chacma baboons in the Namib Desert was observed to survive without water for 116 days, obtaining all their moisture from figs. A more typical diet includes fruit, leaves, roots, and insects.

- Up to 35½ in (90 cm)
- Up to 29½ in (75 cm)
- Up to 88 lb (40 kg)
- Herd, large troop
- Least common

S. Africa

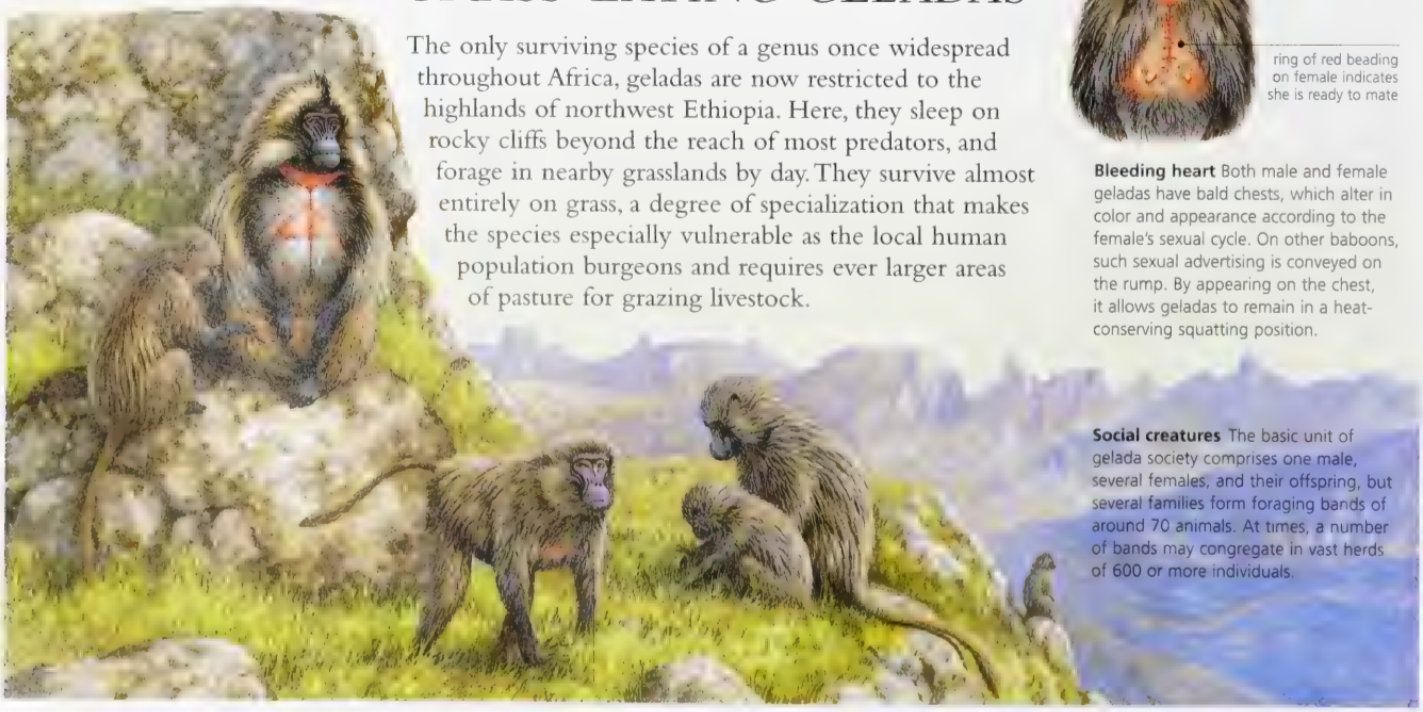



# GRASS-EATING GELADAS

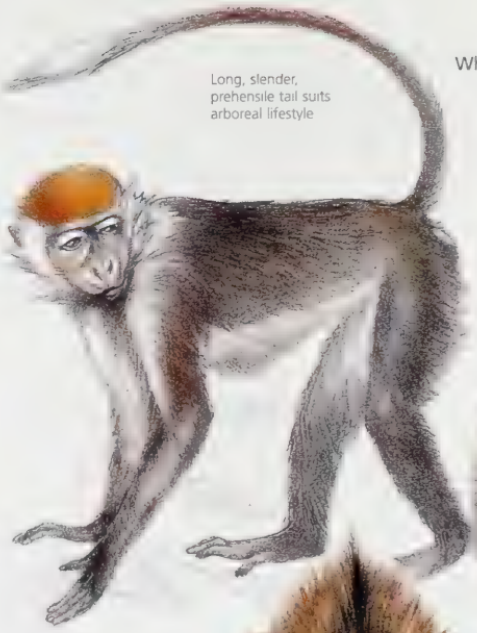
The only surviving species of a genus once widespread throughout Africa, geladas are now restricted to the highlands of northwest Ethiopia. Here, they sleep on rocky cliffs beyond the reach of most predators, and forage in nearby grasslands by day. They survive almost entirely on grass, a degree of specialization that makes the species especially vulnerable as the local human population burgeons and requires ever larger areas of pasture for grazing livestock.

**Bleeding heart** Both male and female geladas have bald chests, which alter in color and appearance according to the female's sexual cycle. On other baboons, such sexual advertising is conveyed on the rump. By appearing on the chest, it allows geladas to remain in a heat-conserving squatting position.

***On alert*** *The dominant male in a troop is always on the alert for challenges from bachelor bands.*



**Social creatures** The basic unit of gelada society comprises one male, several females, and their offspring, but several families form foraging bands of around 70 animals. At times, a number of bands may congregate in vast herds of 600 or more individuals.




White-cheeked mangabey
*Lophocebus albigena*

Drill
*Mandrillus leucophaeus*

Mandrill
*Mandrillus sphinx*

Agile mangabey
*Cercocebus galeritus*

## FACT FILE

**Mandrill** The largest of all monkeys, Africa's mandrills are instantly recognizable by their striking red and blue faces. During the day, they come down from their sleeping trees to search for fruit, seeds, insects, and small vertebrates on the rain-forest floor. Troops of up to 250 mandrills are made up of smaller multi-male groups, each with about 20 animals led by a dominant male who fathers most of the young.

Equatorial W. Africa

***Showing off*** To threaten a rival or predator, a male mandrill will spread its arms wide and yawn, displaying its daunting teeth.

***Attractive colors*** In addition to their vibrant faces, male mandrills have a yellow beard, mauve rump, red penis and lilac scrotum. The pink colors are most intense in the dominant male—they seem to be linked to testosterone levels and may be advertising his status.

## CONSERVATION WATCH

**Threatened drills and mandrills** Both drills and mandrills are under threat as logging, farming, and human settlement continue to destroy much of their rain-forest habitat. Both species are [illegible] food, with their [illegible] loud calls making them easy to find. Drills are now endangered. Their numbers [illegible] in the past three [illegible] years. Mandrills are considered vulnerable. [illegible] [illegible] found.

## FACT FILE

**Sykes' monkey** Among this species, a single adult male dominates troops of 10–40 females and their offspring. The females help raise one another's young

Up to 26½ in (67 cm)
Up to 33½ in (85 cm)
Up to 26½ lb (12 kg)
Family band, variable
Locally common

E & S Africa

**Vervet monkey** Although it prefers to live in woodland along rivers, this adaptable monkey is found in many habitats, including human settlements

Up to 24½ in (62 cm)
Up to 28½ in (72 cm)
Up to 20 lb (9 kg)
Herd, troop
Declining

Sub-Saharan Africa

**Diana monkey** Spending their lives high in the trees, Diana monkeys live in single-male groups of 15 or more individuals. The young gain their arboreal skills through constant play

Up to 23½ in (60 cm)
Up to 31½ in (80 cm)
Up to 16½ lb (7.5 kg)
Family band
Endangered

Coastal W Africa

**Mona monkey** Like many other Old World monkeys, this small primate stores fruit and insects in its cheek pouches while it forages

Up to 27½ in (70 cm)
Up to 27½ in (70 cm)
Up to 15½ lb (7 kg)
Herd, troop
Locally common

N & C Africa

### MIXING SPECIES

Large groups of monkeys sometimes contain more than one species. In East Africa, for example, Sykes' and redtail monkeys form stable associations, traveling and feeding together. Such an arrangement reduces the risk of predation while avoiding the increased competition for food involved in a larger single-species group

Redtail monkey
*Cercopithecus ascanius*

Grasping hands for gripping branches and collecting fruit

Allen's swamp monkey
*Allenopithecus nigroviridis*

Lives in swamp forests and forages on ground or in shallow water

Chestnut fur on underside of tail gave rise to common name

Webbing between digits helps with swimming

Patas monkey
*Erythrocebus patas*

Slender legs of equal length allow monkey to run at speeds of up to 35 mph (55 km/h)

Red-eared monkey
*Cercopithecus erythrotis*

## MONKEY SIGNALS

Sometimes referred to as guenons, the monkeys in the genus *Cercopithecus* all use a range of signals to communicate with other members of their species While many of these signals are vocal, encompassing barks, grunts, screams, booms, and chirps, others are tactile or visual. Nose-to-nose contact is a form of friendly greeting used by many species. Tail position can indicate an animal's level of confidence. Staring, head-bobbing, and yawning are often used as a threat display to intimidate a potential opponent, while a display of clenched teeth is a fear grimace, employed as a gesture of appeasement.

***On the nose*** *A nose-to-nose greeting between two redtail monkeys is often followed by grooming or play.*

***Confident tail*** *Among vervets, tail position indicates whether the animal is fearful or not. When on all fours, a tail arched over the body conveys great confidence.*

***Raising the alarm*** *To warn the troop of a predator, a vervet uses specific alarm calls: a "chutter" sound for snakes makes the monkeys stand up and check the grass; a double cough for eagles prompts them to look up in the air and take cover; and a barking call for leopards sends them running to the trees*

## CONSERVATION WATCH

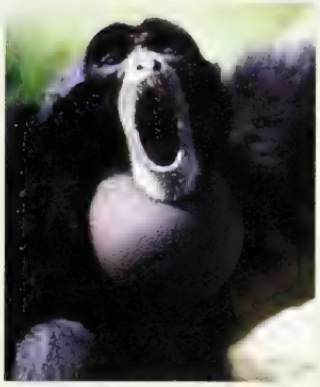
**Patas vulnerability** This terrestrial monkey lives on the savannas of central Africa. Already vulnerable to rainfall fluctuations in this drought-prone region, more and more patas monkeys are being killed by hunters for their meat and by farmers because they feed on crops. Their habitat is also becoming increasingly fragmented by human activities.

# APES

CLASS Mammalia
ORDER Primates
FAMILIES 2
GENERA 5
SPECIES 18

Like humans, apes are intelligent and quick to learn, form complex social groups, and spend years on the care of each young. They are divided into two families: the gibbons of Hylobatidae, and the great apes—orangutans, chimpanzees, gorillas—of Hominidae, which includes humans. Although apes and Old World monkeys have a similar nose shape and dental structure and are grouped together as catarrhine primates, they differ in many ways. Apes have skeletons suited to sitting or standing upright. They have no tail, their lowest vertebrae fused to form the coccyx instead. Their spines are shorter, their chests are barrel-shaped, and their shoulders and wrists are very mobile.

**Parenthood** All infant apes stay dependent on their parents for a long time. Female gorillas usually give birth to a single young, who takes up to 3 years to be weaned. Because more than a third of all infant gorillas die before this, most females take 6–8 years to produce a surviving offspring.



### GIBBON SONGS

Gibbon pairs often begin the day with duets led by the female and punctuated by the male. While these songs may reinforce the pair bond, they are also territorial and act as spacing calls, helping the gibbons to avoid other pairs during their daytime foraging. Many gibbon species feature throat sacs that amplify their calls. Among the siamangs, the largest gibbons, both males and females possess enormous throat sacs. The sacs produce a booming sound as they are inflated, which is followed by a deafening bark or shriek.

## CLEVER APES

Ape societies are organized in various ways. Monogamous gibbons live in pairs with their offspring, making groups of up to six animals. Orangutans with overlapping ranges form loose associations and meet occasionally, but the male tends to be a solitary forager, and the female usually lives just with her single young. Chimpanzee communities involve 40–80 individuals, but these are rarely together at once and tend to forage in smaller groups. Gorillas live in harems, with one dominant male, possibly one or two lower-ranking adult males, several females, and their young.

The gibbons and the great apes evolved into distinct families at least 20 million years ago. Chimpanzees are believed to be the closest relatives of humans, sharing a common ancestor until about 6 million years ago. The great apes appear to work through problems much as humans do. Chimpanzees and orangutans are known to fashion tools in the wild, while in research centers all the great apes have been taught to use implements. By recognizing themselves in mirrors, great apes show a concept of self, and some have been taught to recognize and use symbols such as sign language.

**Moving apes** While all apes other than humans have arms longer than their legs, orangutans and gibbons are the only ones in which the arms are genuinely elongated compared to their trunk. The orangutan's head and body measure about 5 feet (1.5 m), while their arms have a spread of more than 7 feet (2.2 m). Gibbons move by brachiation, using their arms to swing from one branch to another. Orangutans do not brachiate, but clamber slowly through the trees using some combination of all four limbs. Chimpanzees spend up to three-quarters of their time on the ground, but will climb after in trees. Gorillas are apes, terrestrial and rarely climb trees.

### CONSERVATION WATCH

Extensive logging and clearing of tropical forest have placed most apes in jeopardy. The bushmeat trade has also taken a heavy toll. Of the 18 species of apes, 100% are listed on the IUCN Red List, as follows

- 3 Critically endangered
- 7 Endangered
- 3 Vulnerable
- 4 Near threatened
- 1 Data deficient

***A flexible grip*** *The orangutan's strong hands and feet are hook-like, the thumb and big toe are short and the other digits are long*

***Hanging around***

***Energy conservation*** *Long arms allow the orangutan to reach fruit with minimal effort*

Kloss's gibbon
*Hylobates klossii*

White face rings, hands, and feet with reddish or black coat

Lar gibbon
*Hylobates lar*

Throat sac bigger than head

Elongated arm with hook-like, grasping hand

Siamang
*Hylobates syndactylus*

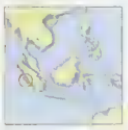
Hoolock
*Hylobates hoolock*

Males are black; adult females are golden or buff, sometimes with black patches

Black gibbon
*Hylobates concolor*

## FACT FILE

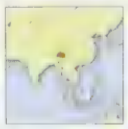
**Kloss's gibbon** To move through the forest, the Kloss's gibbon brachiates and can hurl itself over 30 feet (10 m) between trees. It feeds mostly on fruit, especially sugar-rich figs, but will also eat flowers and insects



Up to 25½ in (65 cm)
None
Up to 17½ lb (8 kg)
Pair
Vulnerable

Mentawai I. (Indonesia)

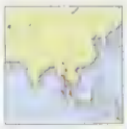
**Hoolock** Found farther north and east than any other gibbon, this large species avoids competition with other primates by preferring especially ripe fruit. Its numbers are now decreasing, however, as hunting and habitat fragmentation take their toll



Up to 25½ in (65 cm)
None
Up to 17½ lb (8 kg)
Pair
Endangered

N.E. India, Bangladesh, S.W. China, Myanmar

**Lar gibbon** To find the ripe fruit and new leaves and buds that make up its entire diet, this gibbon swings to the edge of the tree canopy, where these foods are most abundant.



Up to 25½ in (65 cm)
None
Up to 17½ lb (8 kg)
Pair
Near threatened

S. China, Myanmar, Thailand, Malaya, Sumatra

**Black gibbon** This gibbon is born with a golden or buff coat, which turns black at about 6 months of age Males remain black, but when females mature they turn golden or buff again, sometimes retaining patches of black

Up to 25½ in (65 cm)
None
Up to 17½ lb (8 kg)
Pair
Endangered

S. China, N. Vietnam

**Siamang** The largest gibbon, the siamang spends 5 hours a day eating often hanging by one arm as it feasts While it consumes a lot of [illegible] some insects and [illegible] to half of its diet is mad[illegible]

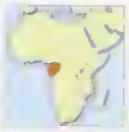
## FACT FILE

**Orangutan** Asia's only great apes, orangutans are also the world's largest arboreal mammals. Most hardly ever descend to the forest floor, moving through the forest by swinging a tree back and forth until they can grasp the next one. Every night, an orangutan constructs an elaborate nest in the crown of a tree and covers itself with vegetation to sleep.

Up to 5 ft (1.5 m)
None
Up to 200 lb (90 kg)
Solitary, pair
Endangered

Borneo, Sumatra

**Western gorilla** The largest of all primates, male gorillas grow until they are about 12 years old, developing a saddle of silvery-white hair on the back, hence the term "silverback" for a mature male. Gorillas spend most of their time on the ground, covering substantial distances on all fours



Up to 6 ft (1.8 m)
None
Up to 400 lb (180 kg)
Variable
Endangered

C. Africa

## TOOL TIME

The ingenuity and manual dexterity of chimpanzees are demonstrated by their tool use. They strip twigs and grass stems to make wands for probing ant and termite nests. Specially selected stones are used to open nuts and hard-shelled fruit. During displays of strength or hunting, some chimps use sticks and rocks as missiles. Tool use [illegible] learned tradition [illegible] varies from one chimp [illegible]

Up to 3 ft (93 cm)
None
Up to 110 lb (50 kg)
Large troop, herd
Endangered

[illegible]

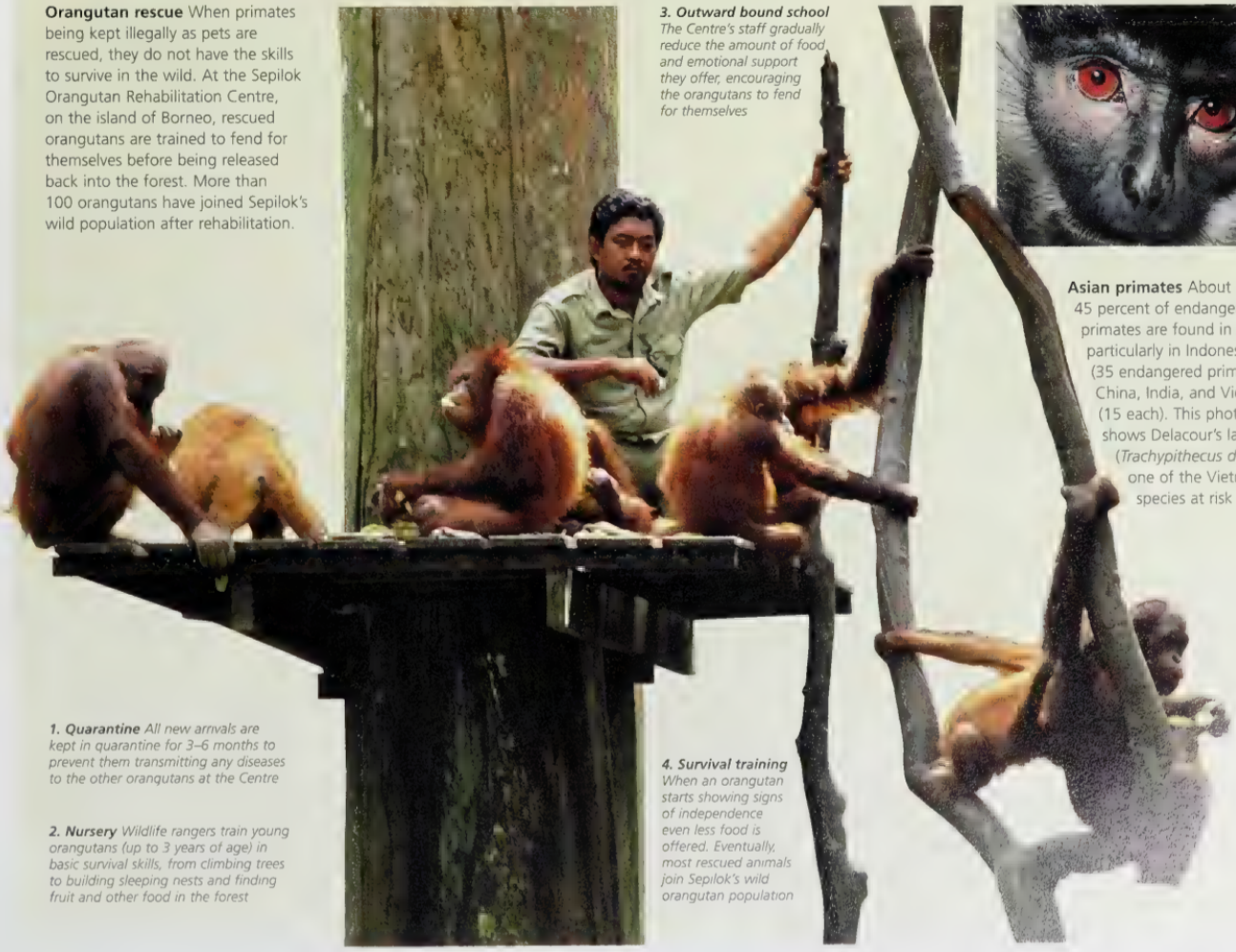
# CONSERVING PRIMATES

According to Conservation International, 195 primate species and subspecies—about a third of all primate types—are at risk of extinction within the next few decades. About half of all colobus monkeys and gibbons are threatened, while in the family Hominidae, humans are the only secure species, with all of the great apes considered endangered. The trade in live animals as pets or for biomedical research has contributed to the declining numbers, as has the hunting of primates as food or pests. The greatest threat, however, is from habitat destruction through logging, land clearing, and collection of wood for fuel. Because primates reproduce slowly, their populations take a long time to recover. Almost all are tropical animals and live in poorer countries, so conservation efforts are complicated by the pressing needs of the growing human population.

**Extinction** Miss Waldron's red colobus monkey (*Procolobus badius waldroni*), once found in Ghana and Côte d'Ivoire, was the only primate to be documented as extinct during the 20th century. The extinction appears to have been caused by hunting for the bushmeat trade, exacerbated by logging operations that gave access to formerly remote forests. Many living primate species continue to face similar threats. While the live-animal trade in endangered species has been outlawed, some primates are still captured and sold illegally as pets or for medical research, and many are killed as bushmeat.

**Habitat destruction** When an area of rain forest is cut down, several primate species can be affected at once and the damage is permanent. Rain-forest soil is thin and low in nutrients, but it supports lush plant growth because the nutrients are efficiently recycled by the ecosystem. Once the tree cover is lost, the soil is washed away by rain and the area soon becomes barren.

**Orangutan rescue** When primates being kept illegally as pets are rescued, they do not have the skills to survive in the wild. At the Sepilok Orangutan Rehabilitation Centre, on the island of Borneo, rescued orangutans are trained to fend for themselves before being released back into the forest. More than 100 orangutans have joined Sepilok's wild population after rehabilitation.



***3. Outward bound school*** *The Centre's staff gradually reduce the amount of food and emotional support they offer, encouraging the orangutans to fend for themselves*

***1. Quarantine*** *All new arrivals are kept in quarantine for 3–6 months to prevent them transmitting any diseases to the other orangutans at the Centre*

***2. Nursery*** *Wildlife rangers train young orangutans (up to 3 years of age) in basic survival skills, from climbing trees to building sleeping nests and finding fruit and other food in the forest*

***4. Survival training*** *When an orangutan starts showing signs of independence even less food is offered. Eventually, most rescued animals join Sepilok's wild orangutan population*

**Asian primates** About 45 percent of endangered primates are found in Asia, particularly in Indonesia (35 endangered primates), China, India, and Vietnam (15 each). This photograph shows Delacour's langur (*Trachypithecus delacouri*), one of the Vietnamese species at risk

# CARNIVORES

CLASS Mammalia
ORDER Carnivora
FAMILIES 11
GENERA 131
SPECIES 278

From massive polar bears to little weasels, speedy cheetahs to lumbering elephant seals, pack-living wolves to solitary tigers, members of the order Carnivora display remarkable diversity. Although they are commonly referred to as carnivores, a term also used for any meat-eating animal, some of them eat meat only rarely, if at all. The one thing members of Carnivora have in common is a predatory ancestor with four carnassial teeth—scissor-like molars that can shear through meat. Most carnivores retain the carnassial teeth, which sets them apart from other meat-eating mammals. In mainly insectivorous or herbivorous carnivores, the carnassial teeth have been modified for grinding.

**Prowling for meat** Like most animals that belong to the order Carnivora, the jaguar is a predator and mainly eats meat. It has [illegible] A solitary hunter, it rules on [illegible] prey. The large wild cat [illegible] across [illegible] while the [illegible] [illegible] by [illegible]

**Vegetarian carnivore** [illegible]

**Sweet tooth** Originally classified as a primate, the kinkajou is a nocturnal, tree-dwelling carnivore. A prehensile tail allows it to hang upside down as it feeds on fruit or uses its long, narrow tongue to gather nectar or honey. It sometimes supplements this sweet diet with insect prey

## PRIME HUNTERS

As the dominant land predators on all continents except Antarctica, carnivores are built for hunting. They rely on their acute senses of sight, hearing, and smell to help them detect prey. The complex ear region, which often features more than one inner chamber, increases sensitivity to the frequencies that are produced by their prey species.

Intelligence, agility, and speed help carnivores stalk, chase, and catch their prey efficiently. Even apparently cumbersome species such as bears are capable of impressive sprints, while the cheetah is the fastest land animal in the world. All carnivores have fused bones in the forefeet, a feature that helps absorb the shock of running. A reduced collarbone increases the mobility of the shoulder muscles, allowing a longer stride and greater speed.

To kill their prey, carnivores generally use their strong jaws and sharp teeth. Weasels smash the prey's skull by biting into the back of its head. Cats strike small prey at the neck to snap the spinal cord, while dogs dislocate the neck by violently shaking the animal in their jaws.

**Adaptable animals** Carnivores are found in almost all of Earth's habitats. Polar bears, arctic foxes, and these gray wolves survive in the icy landscape of the Arctic; otters and seals spend most of their time in the water; big cats prowl both jungles and savanna; and jackals live in deserts

Cooperative hunting allows wolves, lions, and other pack animals to tackle much larger prey such as buffalo and wildebeest.

Almost all the larger meat-eating carnivores hunt vertebrates. Smaller carnivores mostly eat invertebrates, which are easier to catch but can rarely sustain a large animal. Various carnivores concentrate on termites, worms, fish, and crustaceans, and some are largely vegetarian, with a preference for berries, other fruit, nuts, seeds, nectar, or bamboo, but all tend to be opportunistic feeders and will take advantage of any easy meal that presents itself.

About 50 million years ago, the order Carnivora split into two lineages. The cat-like carnivores include civets (family Viverridae), cats (Felidae), hyenas (Hyaenidae), and mongooses (Herpestidae). Dog-like carnivores include dogs (Canidae), bears (Ursidae), raccoons (Procyonidae), weasels (Mustelidae), and seals (Otariidae and Phocidae). Until recent years, seals were often treated as a separate order known as Pinnipedia, but genetic studies indicate that they share a common ancestry with the other carnivores.

**Group living** For many smaller carnivores, living in a group helps to reduce the risk of predation. In suricate troops, which are made up of two or three family units, members take turns to watch for danger.

**Designed to hunt** The skeleton of a cat displays many of the anatomical features that have made carnivores such effective predators. A flexible spine, long limbs, fused wrist bones, and reduced collarbone all contribute to the cat's speed and agility.

## INTRODUCING CARNIVORES

The exceptional hunting abilities of carnivores have inspired many misguided attempts to use them for pest control in regions where they are not native. The consequences of such introductions have usually been disastrous. The native fauna of New Zealand is under threat from stoats (right), which were introduced in the 1880s to take care of a rabbit problem. In the Caribbean and Hawaii, the small Indian mongooses (*Herpestes javanicus*) imported to control rodents and snakes ended up spreading rabies instead. On a number of the world's far-flung islands, feral cats, which were supposed to get rid of rats, preferred the easier prey of flightless birds and destroyed their populations.

# THE DOG FAMILY

CLASS Mammalia
ORDER Carnivora
FAMILY Canidae
GENERA 14
SPECIES 34

Perhaps no creatures have such an ambivalent relationship with humans as the dogs, wolves, coyotes, jackals, and foxes that make up the carnivore family Canidae. Domesticated at least 14,000 years ago, dogs were the first animals to enter a partnership with humans and have been used extensively for hunting, guarding, warmth, and companionship. At the same time, wild canids have been relentlessly persecuted, blamed for the loss of livestock and the spread of rabies and hunted for sport and fashion. While some species such as red foxes and coyotes have adapted and thrived in the midst of urban development, others such as red wolves are on the verge of extinction.

**A wide distribution** Originating in North America 34–55 million years ago, wild canids now occur on every continent except Antarctica, but are absent from some islands, including Madagascar, Hawaii, the Philippines, Borneo, and New Zealand They were introduced to New Guinea and Australia in prehistoric times. The domestic dog is now found worldwide.

## GRASSLAND CARNIVORES

Most canids live in open grasslands, where they capture their prey either by sudden pouncing or by extended pursuit. With their slender build, muscular, deep-chested bodies, and long, sturdy legs, they are capable of great endurance. In addition to the fused foot bones common to other carnivores, canid forelimb bones are locked to prevent them rotating as they run. A pointed muzzle houses the large scent organs that allow canids to track prey over long distances, while large, erect ears contribute to their acute hearing.

Opportunistic and adaptable, canids prefer to eat freshly killed meat but will take advantage of whatever food is locally available and may eat fish, carrion, berries, and human garbage. Their social organization is similarly flexible, varying between and within species and often reflecting their diet. Smaller species such as jackals and foxes mostly eat small animals and often live alone or in pairs. Larger species such as gray wolves and African wild dogs usually live and hunt in hierarchical social groups, cooperating to bring down prey larger than themselves. Canids that hunt especially large animals tend to live in the largest groups, while in areas where smaller prey are abundant, some gray wolves choose to live in pairs.

Group living confers benefits other than hunting advantages, however, and some canids live communally but hunt alone. These animals work together to care for the pack's young and defend their territory from rival packs.

**Cooperative hunters** Gray wolves usually live in family units of 5–12 dogs dominated by an alpha pair. The pack cooperates to snare larger prey such as deer. They most often target a young, old, or weak herd member, pursuing it until it is exhausted

**Walking on tiptoes** Members of the dog family have elongated feet and move by digitigrade locomotion: walking on just the toes rather than on the entire sole of the foot. As the claws cannot be retracted, they become blunt from wear. In a dog's forefeet, fused bones at the wrists help to absorb the impact of running

### FAMILY LIFE

Unusually among mammals, a lifelong monogamous pair bond forms the basis of the jackal social unit. Both parents take an active role in caring for the young, who are nursed for about 8 weeks and then fed regurgitated food for several weeks more. In many jackal families, one or two young stay with the parents for a year after reaching sexual maturity and help to raise the next litter.

Slender, pointed muzzle

Coyote
*Canis latrans*

Drooping, bushy tail with black tip

Reddish brown forelegs, feet, and muzzle

Red wolf
*Canis rufus*

Smaller than gray wolf, with longer ears and shorter fur

Gray wolf
Alaskan form
*Canis lupus tundrarum*

Size and fur color of gray wolf vary according to location

Gray wolf
Scandinavian form
*Canis lupus lupus*

## COYOTE COMMUNICATION

While many coyotes are solitary, others live and hunt in pairs or larger packs Like other canids, coyotes use scent marking, facial expressions, body and tail posture, and a range of squeaks, yelps, and howls to communicate

friendly

submissive

playful

attacking

defending

## CONSERVATION WATCH

**Waning wolves** While the versatile coyote's numbers and range have been expanding, wolves have been suffering. Once found throughout most of the Northern Hemisphere, gray wolves now survive in just a handful of restricted areas in North America and Eurasia. Red wolves are critically endangered, with only some 200 individuals remaining in the wild. Both wolf species are the target of reintroduction campaigns

## FACT FILE

**Side-striped jackal** Rather than [illegible] the kills of other [illegible] particular [illegible]

Up to 16 in (4 [illegible]

Uncommon

**Golden jackal** The most widely [illegible] edge of human settlement [illegible] in Egyptian mythology

**Black-backed jackal** [illegible] be active day or night. About half of its diet consists of insects, with smal [illegible] up the rest [illegible] share the care of their pup [illegible]

Up to 35½ in (9[illegible]

Up to 26½ lb (12 kg)

[illegible] Africa

**Ethiopian wolf** [illegible] adults [illegible] endangered ma[illegible]

Up to 42 lb (19 [illegible]

Solitary, small [illegible]

Critically endangered

[illegible] Ethiopia

**Dingo** Probably brought to Australia [illegible]

**Dhole**
*Cuon alpinus*

Short, broad muzzle suits almost exclusive diet of large vertebrate prey

Paws covered in dense fur during winter

**Arctic fox winter coat**
*Alopex lagopus*

**Arctic fox summer coat**
*Alopex lagopus*

Teeth include up to eight extra molars for grinding up termites, dung beetles, and other insects

**Bat-eared fox**
*Otocyon megalotis*

**Cape wild dog (African wild dog, African hunting dog)**
*Lycaon pictus*

Each Cape wild dog has a unique coat pattern

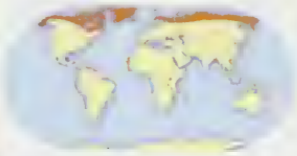
**Raccoon dog**
*Nyctereutes procyonoides*

Molts twice a year as it grows a thick winter coat followed by a lighter summer coat

## FACT FILE

**Arctic fox** For winter, this fox grows a white coat to match its snowy habitat and feeds on marine mammals, sea birds, fish, and crustaceans, as well as on stored food. As summer approaches its coat turns brown or black to blend in with the tundra vegetation

- Up to [illegible] cm
- Up to 16 in (40 cm)
- Up to 20 lb (9 kg)
- Solitary
- Common



N. North America, N. Eurasia, Iceland, Greenland

**Cape wild dog** This canid is entirely carnivorous. After a kill, the healthy adult dogs will regurgitate food for any young, sick, or wounded pack members

- Up to 35½ in (90 cm)
- Up to 16 in (40 cm)
- Up to 79½ lb (36 kg)
- Solitary, small group
- Endangered

E. & S. Africa

## UNUSUAL CANID

The raccoon dog is the only canid to enter a dormant state in winter and the only canid that does not bark. While most other canids live in open grasslands, the raccoon dog prefers the dense undergrowth of forests. Originally from East Asia, it was introduced to Europe by the fur trade

***Raccoon resemblance***
[illegible]

## CONSERVATION WATCH

Of the 34 species of canids [illegible] are listed on the IUCN Red [illegible] as follows:

1 Extinct
2 Critica[illegible]
1 Endan[illegible]
2 [illegible]
1 [illegible]
[illegible]
[illegible]

## FACT FILE

**Kit fox** Found in arid regions, the kit fox avoids the heat of the day by resting in its underground den, coming out at night to hunt rabbits and kangaroo rats. This fox relies on the moisture in its prey for fluids and therefore kills more animals than are needed to meet its energy requirements alone.

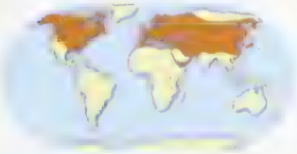
- Up to 20½ in (52 cm)
- Up to 12 [illegible] 32 cm
- Up to 6 lb (2.7 kg)
- Solitary
- Conservation dependent

S.W. USA & N. Mexico

### THE SUCCESSFUL RED FOX

One of the most widely distributed species in the world, the red fox's versatile feeding habits have allowed it to thrive in forest, prairie, farmland, and suburban areas. Hunted for sport and bred for fur, this canid has been blamed for killing poultry and spreading rabies. Where it has been introduced, as in Australia, the red fox poses a major threat to native fauna

- Up to 19½ in (50 cm)
- Up to 13 in (33 cm)
- Up to 13 lb (6 kg)
- Solitary, pair
- Common



North America, Europe, N. & C. Asia, N. Africa, Arabia; introd. Australia

*Fox feast* Red foxes will eat almost anything, from rodents and rabbits to fruit and garbage

## CONSERVATION WATCH

**Swift reintroduction** Once ranging throughout the North American prairies, the swift fox lost habitat to agriculture and urbanization and was [illegible] and persecuted. By 1978, it had disappeared from Canada, but reintroduction programs have established small populations in Alberta and Saskatchewan and the species has moved from endangered to lower risk status.

Tibetan fox
*Vulpes ferrilata*

Broad ears listen for rustling rodents

Corsac fox
*Vulpes corsac*

Blanford's fox
*Vulpes cana*

Displays cat-like movements

Kit fox
*Vulpes macrotis*

Pale fox
*Vulpes pallida*

Red fox
North American form
*Vulpes vulpes fulva*

Short reddish summer coat replaced by longer, thicker gray coat for winter

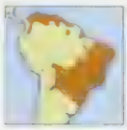
Swift fox
*Vulpes velox*

Bengal fox
*Vulpes bengalensis*

Red fox
Central European form
*Vulpes vulpes crucigera*

## FACT FILE

**Crab-eating fox** An opportunistic feeder, this fox often eats crabs and other crustaceans during the wet season, but shifts to insects in the dry season. Its diet also features fruit, turtle eggs, small mammals, birds, reptiles, amphibians, fish, and carrion



Up to 30 in (76 cm)
Up to 13 in (33 cm)
Up to 17½ lb (7.9 kg)
Pair
Common

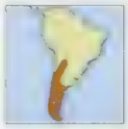
Colombia to Argentina except Amazon basin

**Maned wolf** This omnivorous canid eats large amounts of bananas, guavas, and other fruit as well as animals such as armadillos, rabbits, rodents, snails, and birds. It hunts at night in a fox-like manner, suddenly pouncing on its prey

Up to 39½ in (100 cm)
Up to 16 in (40 cm)
Up to 53 lb (24 kg)
Solitary, pair
Near threatened

Brazil to Paraguay & Argentina

**Argentine gray fox** This nocturnal fox usually lives in small groups made up of a mating pair, their offspring, and sometimes a second adult female who helps to raise the young. The group maintains a year-round territory



Up to 26 in (66 cm)
Up to 16½ in (42 cm)
Up to 12 lb (5.4 kg)
Solitary, pair
Locally common

Chile & Argentina

**Bush dog** With its squat stature and short face, the bush dog looks less like a dog than any other canid. Packs of up to 10 animals forage together in forest undergrowth, keeping in touch via high-pitched peeps and whines.

Up to 29½ in (75 cm)
Up to 5 in (13 cm)
Up to 15½ lb (7 kg)
Solitary to large group
Vulnerable

W. Panama to Paraguay & N. Argentina

**Pampas fox** When threatened by humans, the pampas fox freezes and may remain motionless if handled. Pairs live together only during the mating season and share the care of the young

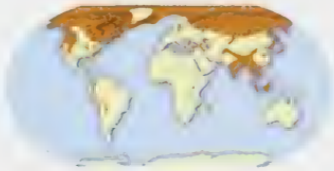
Up to 28½ in (72 cm)
Up to 15 in (38 cm)
Up to 17½ lb (7.9 kg)
Solitary, pair
[illegible]

E. Bolivia & S. Brazil to N. Argentina

# THE BEAR FAMILY

CLASS Mammalia
ORDER Carnivora
FAMILY Ursidae
GENERA 6
SPECIES 9

In spite of their fearsome reputation, bears tend to be the most herbivorous of the carnivores. Only one species, the polar bear, is primarily a meat-eater, while berries, nuts, and tubers make up the bulk of the American black bear's diet, the sloth bear feeds mostly on insects, and the giant panda eats almost nothing but bamboo. The first bear species emerged from the canid family 20–25 million years ago in Eurasia. About the size of a raccoon, these early creatures had a long tail and the shearing carnassial teeth common to most members of Carnivora. Over time, most bears became much bigger, their tails shortened, and their carnassials were flattened for grinding vegetable matter.



**Northern diversity** Most abundant in the Northern Hemisphere, bears live in Europe, Asia, and North and South America. The brown bear was also found in North Africa until the 1800s. Today, all but two bear species are in danger, victims of habitat loss and overhunting

**Fish feeder** In the northwest coastal regions of North America, brown bears will wait at waterfalls to catch spawning salmon as they swim upstream. This annual glut of fish provides important protein before winter begins.

**Full size** Grizzly bears (*Ursus arctos horribilis*) will attempt to intimidate a rival or foe by rearing up on their hindfeet and even walking bipedally for a short distance. The upright stance increases their already impressive size. They may also growl and display their long canine teeth.

## STRENGTH AND BULK

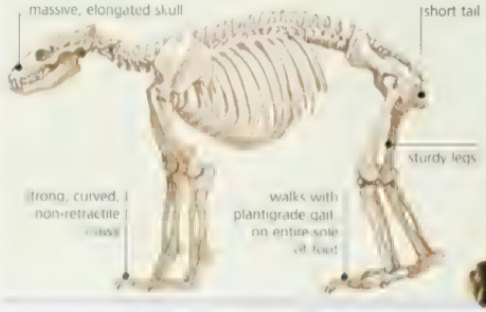
Although the red panda may weigh only about 6 pounds (3 kg), most bears classified in the Ursidae family are substantial animals, with the polar bear and brown bear vying for the title of the largest terrestrial carnivore. As they often spend more of their time foraging than hunting, bears are built for strength rather than speed, with a stocky, muscular body, thick legs, and a massive skull. An enlarged snout reflects their keen sense of smell. Vision and sound are less important, and their eyes and ears are relatively small.

Bears are found in the tropics, but it is in the cold northern lands that they are most numerous. Here, their great size allows them to put on fat deposits through spring and summer when food is abundant. When the weather cools, the bears retreat to a den or cave and enter a long sleep that can last half the year. During this dormant period, they live entirely on their body fat; they do not eat, urinate, or defecate and their heart and respiration rates drop. Unlike in true hibernation, however, their body temperature hardly falls. Remarkably, females give birth to young during the winter dormancy, maximizing the cubs' chance to grow and accumulate fat deposits before the next winter.

Most bears are solitary, although cubs often stay with the mother for 2–3 years. Rival males can be aggressive in the breeding season, with fights resulting in injury or even death.

### DELIBERATE MOVEMENT

Bears usually move slowly and deliberately on all fours, but are capable of great bursts of speed when pursuing prey. They walk with a plantigrade gait, placing the entire sole on the ground. This not only supports their great bulk, but also allows them to stand up on their hindfeet. While mainly terrestrial, most bears are also agile climbers.



Himalayan brown bear
*Ursus arctos isabellinus*

Brown bear's coat can be brown, blonde, silver-tipped or nearly black

Pronounced shoulder hump

American black bear
*Ursus americanus*

Black bear's coat can be black or brown

European brown bear
*Ursus arctos arctos*

Massive bulk helps polar bear withstand cold and store fat for times of scarcity

Polar bear
*Ursus maritimus*

Largest species of bear

Large, paddle-like paws for swimming

Largest of all brown bear subspecies

Kodiak bear
*Ursus arctos middendorffi*

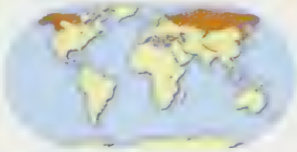
Male is twice as large as female

Asiatic black bear
*Ursus thibetanus*

## FACT FILE

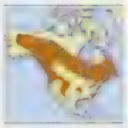
**Brown bear** This species once lived throughout Eurasia and North America and south to North Africa and Mexico. Its subspecies include the European brown bear (*Ursus arctos arctos*), the North American brown bear or grizzly (*U. a. horribilis*), the Kodiak bear (*U. a. middendorffi*), and the Himalayan brown bear (*U. a. isabellinus*).

- Up to 9 ft (2.8 m)
- Up to 8 in (21 cm)
- Up to 1,429 lb (600 kg)
- Solitary
- Locally common



Pockets in N.W. North America, Wyoming, N. & N. Europe, Himalayas, Japan

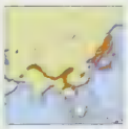
**American black bear** Easily the most common bear, this species has adapted to a range of habitats and varies its omnivorous diet with the season.



- Up to 7 ft (2.1 m)
- Up to 7 in (18 cm)
- Up to 330 lb (240 kg)
- Solitary
- Locally common

Forested North America, nearby islands

**Asiatic black bear** This primarily herbivorous species readily climbs trees to gather fruit and nuts. To startle predators such as tigers, it will stand up and display its white chest mark.



- Up to 6 ft (1.9 m)
- Up to 4 in (10 cm)
- Up to 375 lb (170 kg)
- Solitary
- Vulnerable

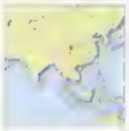
Afghanistan & Pakistan to China, Korea & Japan

## BEAR PAWS

The feet of bears reflect their varied habitats and diet. American black bears have hook-like claws for climbing trees and digging up roots. The giant panda's feet are unusually large, part of which covers a modified wrist bone that acts as a thumb.

## FACT FILE

**Giant panda** This bear consumes up to 40 percent of its weight in bamboo per day, selecting shoots in spring, leaves in summer, and stems in winter. It does not hibernate during winter.



- Up to 5 ft (1.5 m)
- Up to 4 in (10 cm)
- Up to 355 lb (160 kg)
- Solitary
- Endangered

Isolated mountains in W. China

**Red panda** This species was once placed in the raccoon family because of a superficial resemblance, but genetic studies place it with the giant panda. It sleeps in trees by day and eats bamboo and fruit on the ground at night.

- Up to 25½ in (65 cm)
- Up to 19 in (48 cm)
- Up to 13 lb (6 kg)
- Pair
- Endangered

Nepal to Myanmar & W. China

**Sloth bear** After ripping open termite mounds and ant nests with its long, curved claws, this bear uses its long tongue to suck up the insects. It also climbs trees to extract honey from hives.

- Up to 6 ft (1.8 m)
- Up to 5 in (12 cm)
- Up to 320 lb (145 kg)
- Solitary
- Vulnerable

Sri Lanka, India, Nepal

### BAMBOO BEAR

As China's human population has burgeoned, most of the giant panda's habitat has been destroyed. Only about 1,000 pandas remain in the wild, restricted to isolated mountain pockets of bamboo forest. Widely recognized as a symbol of conservation, the giant panda is still poached for its skin.

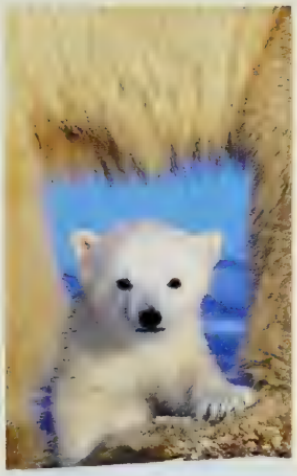
## CONSERVATION WATCH

Of the nine species of bears, seven are listed on the IUCN Red List, as follows:

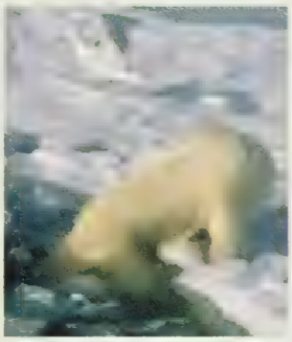
- 2 Endangered
- 1 Vulnerable
- 1 Conservation dependent
- 2 Data deficient

# A YEAR AS A POLAR BEAR

Adapted to the harsh climate of the Arctic, the polar bear lives near the ice-covered water that contains its main prey, the ringed seal. Unlike other bears in cold environments, this semi-aquatic carnivore tends to remain active through winter, but can enter a dormant state and live off its fat deposits at any time of the year if food becomes scarce. Its solitary existence is interrupted only during the breeding season or when adult males fast together in groups known as sloths.



**Cub protection** Male polar bears sometimes kill cubs, presumably to free up the female for breeding. A mother often stands guard over her young and will attack a much larger male to protect them.



**Seal hunter** Polar bears will wait at a seal's breathing hole for hours, ready to pounce on the prey as it surfaces. They feed almost exclusively on seals and other marine mammals.

**Expert swimmer** Using its enormous forepaws as paddles, the polar bear can swim for several hours. On land, it is surprisingly agile and can reach speeds of 25 miles per hour (40 km/h). Dense fur and a layer of fat beneath the skin insulate against the cold.

***April–July feeding*** *Polar bears spend summer preying on the abundant and unwary pups of ringed seals. When the sea ice melts in late July, the bears come ashore and fast until it freezes once more*

***April–May mating*** *Female polar bears spend so long raising their young that they are available for mating only once every 3 years. This leads to intense competition among males for mates.*

***February–April emergence*** *When the cubs are large enough to ven[illegible] ice, the mothe[illegible] of the den. Cubs [illegible] mother for [illegible] learning th[illegible] are crucial to [illegible]*

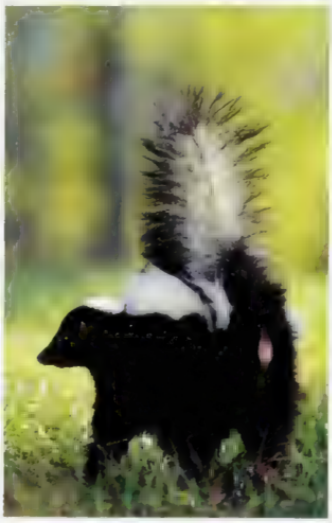
***November–January birth*** *While other polar bears remain active through winter, pregnant females retreat to a snow den, where they give birth to their young. Most litters contain two cubs, who are nursed until around late March*

# MUSTELIDS

CLASS Mammalia
ORDER Carnivora
FAMILY Mustelidae
GENERA 25
SPECIES 65

As a group, the weasels, otters, skunks, and badgers of the family Mustelidae are the most successful and diverse carnivores, with many more species than any other family. Mustelids are found in almost every type of habitat, including forests, deserts, tundra, and fresh and salt water, and may be arboreal, terrestrial, burrowing, semiaquatic, or fully aquatic. While a few species, such as sea otters and wolverines, can weigh more than 55 pounds (25 kg), most members of the family are medium-sized, with the smallest, the least weasel, weighing as little as 1 ounce (30 g). Highly carnivorous, mustelids are voracious hunters and will often tackle prey much larger than themselves.

**Widespread family** Absent only from Australia and Antarctica, mustelids are found throughout Europe, Asia, Africa, and the Americas. Despite their prevalence, only a small number have been well studied. Mustelids have been introduced in many places, either accidentally when they have escaped from fur farms or deliberately to control rodents and rabbits



**Scented defense** Almost all mustelids possess scent glands near the anus that produce musk, a foul-smelling liquid used to mark territory. In skunks, this feature has developed into a defense system, with a spray of noxious musk deterring all but the most determined predators

## RELENTLESS HUNTERS

With an elongated body and short legs, mustelids can pursue rodents and rabbits down burrows. Weasels tend to be slender and lithe, with a flexible spine that allows them to scamper and leap. Badgers, on the other hand, have squat bodies and shuffle along with a rolling gait. Many mustelids are good swimmers and climbers and readily exploit ground- and tree-dwelling prey as well as terrestrial species.

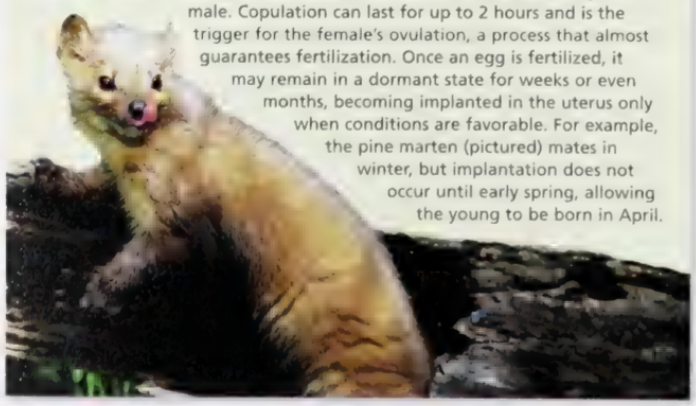
The mustelid head has a low, flat skull and short face with small ears and eyes. Smell is critical, the most developed of the senses, and is used to locate and track prey and for communication, mating, members of a species recognize another by scent. Most mustelids have long, curved, non-retractile claws that they use for digging. Aquatic and semiaquatic species often have webbing between the toes to help with swimming.

**Leaping weasel** Agile and remarkably strong, weasels can run carrying up to half their weight in food. The smallest of all mustelids, the least weasel will relentlessly pursue its prey of mice and voles through thick grass or under snow

Mustelids have a double coat, with a layer of soft, dense underfur interspersed with longer guard hairs. This warm, water-repellent coat enables mustelids to hunt in water and stay active throughout cold winters, but it has also made many species the target of the fur trade.

### A SOLITARY LIFE

Most mustelids tend to be fiercely solitary, coming together only during the breeding season. Mating is often violent and forced on the female by the male. Copulation can last for up to 2 hours and is the trigger for the female's ovulation, a process that almost guarantees fertilization. Once an egg is fertilized, it may remain in a dormant state for weeks or even months, becoming implanted in the uterus only when conditions are favorable. For example, the pine marten (pictured) mates in winter, but implantation does not occur until early spring, allowing the young to be born in April.



Glands at base of tail produce musk scent

**European otter**
*Lutra lutra*

Enters and leaves the water at fixed locations within its home territory

**Smooth-coated otter**
*Lutra perspicillata*

**Neotropical otter**
*Lontra longicaudis*

Fingers lack webbing and claws but have opposable thumb and are highly dextrous and sensitive

**Cape clawless otter**
*Aonyx capensis*

Sensitive whiskers help locate prey

**Giant otter**
*Pteronura brasiliensis*

**Spotted-necked otter**
*Lutra maculicollis*

**Sea otter**
*Enhydra lutris*

Uses stone as tool to crack open sea urchin

Broad, flipper-like back paws with webbing to the tips of the toes

Insulating layer of air trapped between long guard hairs and dense underfur

## FACT FILE

**Neotropical otter** Much of this solitary otter's day is spent diving for fish. It eats small prey in the water but takes larger prey to the shore

Up to 32 in (81 cm)
Up to 22½ in (57 cm)
Up to 33 lb (15 kg)
Solitary
Data deficient

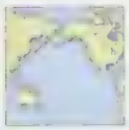
Mexico to Uruguay

**Giant otter** Family groups of several giant otters share a streamside burrow and may forage together. Overhunting has made this species the rarest otter

Up to 4 ft (1.2 m)
Up to 27½ in (70 cm)
Up to 75 lb (34 kg)
Family band
Endangered

S. Venezuela & Colombia to N. Argentina

**Sea otter** This often solitary species can spend its entire life in the ocean, sleeping on the surface and devoting up to 5 hours a day to foraging, but it may rest on shore in large sexually segregated groups. The only non-primate mammal known to employ tools, it will use a stone to dislodge abalone or crack open shellfish



Up to 4 ft (1.2 m)
Up to 14 in (36 cm)
Up to 99 lb (45 kg)
Solitary, rests in group
Endangered

North Pacific

## AQUATIC PAWS

All otters have dextrous paws, but they vary in the degree of webbing and the presence or absence of claws. The paws of most river otters (such as those of the European otter, pictured) are webbed for swimming, clawed for digging, and rounded for walking on land

## CONSERVATION WATCH

**Hunted otters** By 1911, fur hunters had depleted sea otter populations to fewer than 2,000 individuals. Legal protection and reproduction programs have helped increase their numbers to about 1[illegible]00 animals, but the species remains endangered, threatened by poaching, marine oil pollution, persecution by fishing crews, and predation by orcas

## FACT FILE

**Hog badger** Although the hog badger sometimes falls prey to leopards and tigers, it will put up a fight. When threatened, it arches its back, bristles its hair, and growls. It may also emit a noxious fluid from its anal glands

- Up to 27½ in (70 cm)
- Up to 6½ in (17 cm)
- Up to 31 lb (14 kg)
- Not known
- Not known

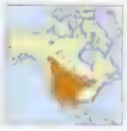
N.E. India to N.E. China & S.E. Asia

**Eurasian badger** While most badgers tend to be solitary, this species lives in extended family groups. A powerful digger, it lives in permanent burrow complexes known as setts, which are passed down through the generations

- Up to 35½ in (90 cm)
- Up to 8 in (20 cm)
- Up to 35½ lb (16 kg)
- Family band
- Locally common

Britain & W. Europe to China, Korea & Japan

**American badger** This solitary species spends much of its time busily digging for rodents such as prairie dogs and ground squirrels. It will rapidly burrow its way out of danger if threatened by a predator on the surface

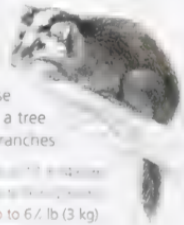


- Up to 28½ in (72 cm)
- Up to 6 in (15 cm)
- Up to 26½ lb (12 kg)
- Solitary
- Locally common

N. Canada to Mexico

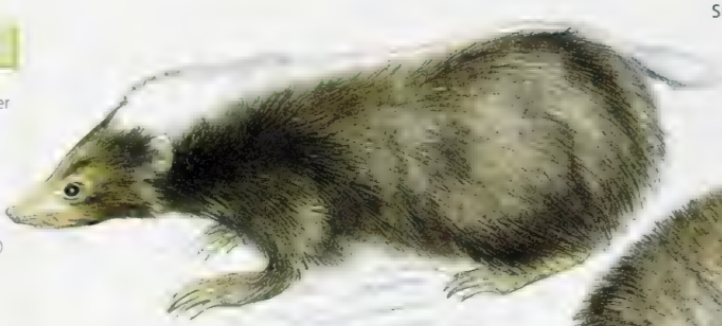
### CLIMBING BADGER

The smallest badger, the Chinese ferret badger forages at night for worms, insects, frogs, small rodents, and fruit. By day, it takes refuge in a burrow or [illegible] hollow, or may use its [illegible] to climb a tree [illegible] branches



- [illegible]
- [illegible]
- Up to 6½ lb (3 kg)
- Not known
- [illegible]

[illegible]



Sunda stink badger
*Mydaus javanensis*

May squirt foul secretion from anal glands when threatened

Hog badger
*Arctonyx collaris*

Elongated snout with pig-like nostrils

Eurasian badger
*Meles meles*

Powerful forelimbs and claws for digging

Chinese ferret badger
*Melogale moschata*

Long, bushy tail

Burmese ferret badger
*Melogale personata*

American badger
*Taxidea taxus*

Hooded skunk
*Mephitis macroura*

Longer, softer fur than striped skunk

Striped skunk
*Mephitis mephitis*

Eastern hog-nosed skunk
*Conepatus leuconotus*

Long claws on forefeet for digging

Spotted skunk
*Spilogale putorius*

Striped hog-nosed skunk
*Conepatus semistriatus*

No white stripe down center of face

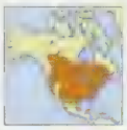
Patagonian hog-nosed skunk
*Conepatus humboldtii*

Andean hog-nosed skunk
*Conepatus chinga*

Bare, projecting nose

## FACT FILE

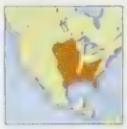
**Striped skunk** This nocturnal creature is an opportunistic feeder and tends to consume a wide range of foods, from small mammals, insects, and fish to fruit, nuts, grains, and grasses. During winter, it becomes inactive and rarely emerges from its den



Up to 31½ in (80 cm)
Up to 15½ in (39 cm)
Up to 14 lb (6.5 kg)
Solitary
Common

N. Canada to Mexico

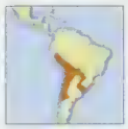
**Spotted skunk** The only skunk that can climb, this species also tends to be more alert and active than other skunks. During the mating season in March and April, males may succumb to "mating madness," spraying any large animal they come across.



Up to 13 in (33 cm)
Up to 11 in (28 cm)
Up to 2 lb (900 g)
Solitary
Common

USA (E. of Rocky Mts)

**Andean hog-nosed skunk** This species dens in rocky crevices, hollow logs, or burrows abandoned by other animals. It pounces on insects and will also hunt small vertebrates such as rodents, lizards, and snakes. It has some resistance to the venom of pit vipers



Up to 13 in (33 cm)
Up to 8 in (20 cm)
Up to 6½ lb (3 kg)
Solitary
Common

South America

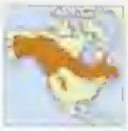
## SKUNK DEFENSE

Before a skunk shoots out foul-smelling musk from its anal glands, it gives an enemy fair warning, raising its tail, stamping its feet, pretending to charge, or even doing a handstand. The skunk's distinctive black and white markings also serve to warn predators that it is a meal best avoided

***Danger display***

## FACT FILE

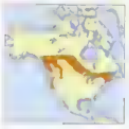
**American marten** This agile mustelid speeds through the trees in pursuit of red squirrels and other prey. It will also hunt birds and insects and forage for fruit, nuts, and carrion. Although primarily a tree-dweller, it is also at ease on the ground or in water.



- Up to 17½ in (45 cm)
- Up to 9 in (23 cm)
- Up to 3 lb (1.3 kg)
- Solitary
- Uncommon

Alaska & Canada to N. California & Colorado

**Fisher** The largest marten, the fisher will tackle a porcupine. While other predators are put off by the porcupine's quills, the fisher stands at the perfect height to bite the unprotected face. Once repeated bites send the porcupine into shock, the fisher will flip it over and feed on its soft belly.

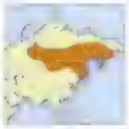


- Up to 31 in (79 cm)
- Up to 16 in (41 cm)
- Up to 12 lb (5.5 kg)
- Solitary
- Uncommon

Alaska & Canada to N. California

### COVETED FUR

A creature of the dense taiga forest of northern Asia, the sable hunts and dens on the forest floor. The species was once found as far west as Scandinavia, but so many animals have been trapped for the fur trade that its range and numbers have been substantially reduced.



- Up to 22 in (56 cm)
- Up to 7½ in (19 cm)
- Up to 4 lb (1.8 kg)
- Solitary
- Uncommon

N. Asia

***Valuable fur*** *The sable's long, silky winter coat has made its pelt one of the most prized by the fur trade.*

## CONSERVATION WATCH

Of the 65 species of mustelids, 35% are listed on the IUCN Red List, as follows:

- 2 Extinct, or extinct in wild
- 7 Endangered
- 8 Vulnerable
- 4 Near threatened
- 6 Data deficient

Great variation in size, from 1–9 oz (35–250 g), depending on location

Coat becomes white in winter in northern part of range

Long-tailed weasel
*Mustela frenata*

Stoat (ermine) winter coat
*Mustela erminea*

Least weasel
*Mustela nivalis*

White winter coat helps stoat blend in with snow

Head paler than body

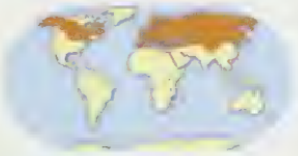
Malaysian weasel
*Mustela nudipes*

Stoat (ermine) summer coat
*Mustela erminea*

## FACT FILE

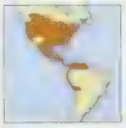
**Least weasel** The smallest of all the carnivores, the least weasel often shares territory with its larger relative, the stoat, but concentrates on smaller prey such as mice and voles. Like the stoat, it can have a white winter coat

- Up to 10 in (26 cm)
- Up to 3 in (8 cm)
- Up to 9 oz (250 g)
- Solitary
- Common



N. Northern Hemisphere; introd. New Zealand

**Long-tailed weasel** Females of this species give birth to an average of six young around May. The young learn how to hunt from their mother and can kill prey at 8 weeks of age.

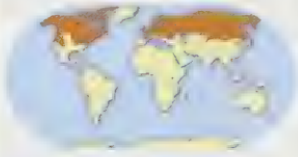


- Up to 10 in (26 cm)
- Up to 6 in (15 cm)
- Up to 13 oz (365 g)
- Solitary
- Common

Canada to Peru & Bolivia

**Stoat** The stoat often sheds its brown summer coat as winter approaches, replacing it with a longer, thicker coat that is entirely white except for the black tail tip. The white fur has long been sought after by the fur industry

- Up to 12½ in (32 cm)
- Up to 5 in (13 cm)
- Up to 13 oz (365 g)
- Solitary
- Common



Northern Hemisphere; introd. New Zealand

## THE WOLVERINE

The largest terrestrial mustelid, the wolverine (*Gulo gulo*) lives in the northern coniferous forest and tundra of Eurasia and North America. It looks somewhat like a bear, but its behavior is definitely mustelid. Remarkably strong and ferocious for its size, it can take down reindeer and caribou, but will scavenge carrion if it is available. Any surplus food is stored in tunnels under the snow, and may be eaten up to 6 months later. The wolverine's massive head houses jaws and teeth that can crunch through large bones and frozen meat. Large feet and a plantigrade gait in which the entire sole is planted on the ground allow the wolverine to travel quickly over snow and outrun hoofed prey. This northern mustelid is also an agile climber and strong swimmer.

## RELENTLESS CARNIVORES

Weasels will pursue prey [illegible] or under snow and ca[illegible] half their own weight [illegible] run. While smal[illegible] mice and voles, a[illegible]

## FACT FILE

**Black-footed ferret** While most mustelids are opportunistic feeders, the black-footed ferret preys almost solely on prairie dogs and uses their burrows for shelter

Up to 18 in (46 cm)
Up to 5½ in (14 cm)
Up to 2½ lb (1.1 kg)
Solitary
Extinct in the wild

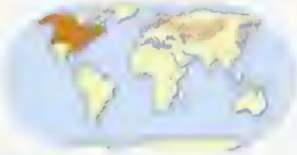
S. Canada to N.W. Texas (until late 1980s), reintrod. Montana, Dakota & Wyoming
Former range

## BATTLE OF THE MINKS

Both the European and American minks are versatile feeders that hunt in or near water. The European mink has been in decline ever since the American mink escaped from European fur farms and became a direct competitor in the wild

**American mink**

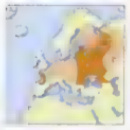
Up to 19½ in (50 cm)
Up to 8 in (21 cm)
Up to 2 lb (900 g)
Solitary
Common



North America, introd. Europe, Siberia
Introduced range

***Mink variation***
*While most American minks are brown about 10 percent have blue-gray fur*

**European mink**



Up to 17 in (43 cm)
Up to 7½ in (19 cm)
Up to 26 oz (740 g)
Solitary
Endangered

France & Spain; Finland to Romania & Georgia
Former range

## CONSERVATION WATCH

**Ferret decline** In 1920, more than 500,000 black-footed ferrets lived on the North American plains but, as humans exterminated their prairie-dog prey, ferret numbers fell until they were thought extinct. A small population found in the 1980s led to a captive-breeding program, but the species remains North America's most endangered mammal.

Tough skin is so loose that ratel can swing around to attack a predator that has bitten down on its neck

Ratel (honey badger)
*Mellivora capensis*

Foul-smelling liquid secreted from anal glands

Patagonian weasel
*Lyncodon patagonicus*

Tayra
*Eira barbara*

Large hindfeet with long claws

Grison
*Galictis vittata*

Stands on hind legs to search for prey

Saharan striped weasel
*Ictonyx libyca*

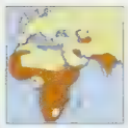
Striped polecat (zorilla)
*Ictonyx striatus*

African weasel
*Poecilogale albinucha*

Marbled polecat
*Vormela peregusna*

## FACT FILE

**Ratel** This mainly terrestrial mustelid will climb trees to reach honey. It has developed a symbiotic relationship with the honey guide bird, which will sing a distinctive song to lead it to a beehive. After opening the hive with its powerful claws, the ratel eats most of the honey, but leaves the wax and bee larvae for the bird. The ratel's omnivorous diet also includes insects and both large and small vertebrates



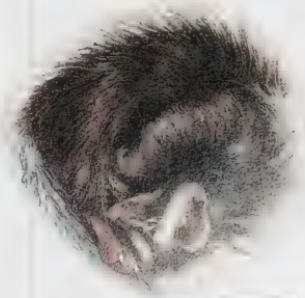
Up to 30½ in (77 cm)
Up to 12 in (30 cm)
Up to 28½ lb (13 kg)
Solitary
Uncommon

W. Africa, sub-Saharan Africa, Arabia, Iraq, Turkmenistan, Pakistan, India

***Shaggy attack***
*The ratel sometimes preys on poisonous snakes. Its long, thick coat and tough skin make it difficult for a snake to bite the flesh*

## PLAYING DEAD

When threatened, a striped polecat will fluff up its long tail and growl or scream. If that does not work, it then squirts the attacker with foul-smelling fluid from its anal glands. As a final resort, the polecat will pretend to be dead. Despite these various defense strategies, striped polecats do fall victim occasionally to predators such as domestic dogs and wild cats. More commonly, however, they are killed by cars. Once one animal has been hit, its family members do not move from the scene and thus often meet the same fate.

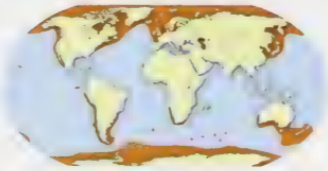


A [illegible]

# SEALS AND SEA LIONS

CLASS Mammalia
ORDER Carnivora
FAMILIES 3
GENERA 21
SPECIES 36

With flexible, torpedo-shaped bodies, limbs modified to become flippers, and insulating layers of blubber and hair, seals, sea lions, and walruses are superbly adapted to a life in water. They have not, however, completely severed their link with land and must return to shore to breed. Collectively known as pinnipeds, these marine mammals were once placed in their own order, but are now considered to be part of Carnivora. Most feed on fish, squid, and crustaceans, but some also eat penguins and carrion and may attack the pups of other seal species. They can dive to great depths in search of prey, with the elephant seal able to stay submerged for up to 2 hours at a time.



**Cold-water creatures** Although monk seals are found in warmer waters, most seals, sea lions, and walruses are restricted to the colder, highly productive seas of the world's polar and temperate regions. The fossil record shows that the three families all originated in the North Pacific. They are now most abundant in the North Pacific, North Atlantic, and Southern oceans

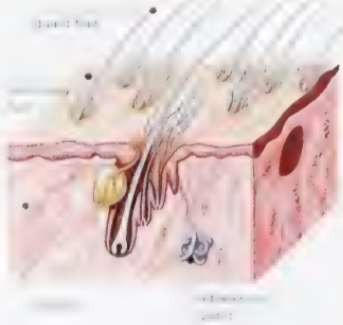
**Communal living** Most pinnipeds are gregarious animals and tend to live in large colonies. Walrus herds can number in the hundreds or even thousands and may be single sex or mixed, with both body and tusk size determining rank

## THREE GROUPS

There are three pinniped families. The Phocidae are known as the true seals. They swim mainly with strokes of their hind flippers, which cannot bend forward to act as feet, making their movement on land particularly ungainly. Although their hearing, especially under water, is good, true seals lack external ears.

Sea lions and fur seals belong to the family Otariidae. These "eared seals" have small external ears. They rely mostly on their front flippers for swimming, and can bend their hind flippers forward when on land, allowing them to walk "four-footed" and sit in a semi-upright position.

The third family, Odobenidae, contains a single species, the walrus, instantly recognizable by the long canine teeth that form tusks on both sexes. Like true seals, walruses use their hind flippers for swimming and lack external ears. Like eared seals, however, walruses can bend their hind flippers forward.



insulating layers

### BRINGING UP BABY

All pinnipeds return to land or ice to give birth and mate. Mating takes place just days after the usually single pup is born, but the fertilized egg does not become implanted in the uterus for months. This delayed implantation allows birthing, nursing, and mating to occur in one season so that the animals live on land, where they are most vulnerable, only once a year. Pups are dependent for varying lengths of time. Harp seals (right), for example, are nursed for only 12 days or so, while walruses stay with their mother for 2 years

### CONSERVATION WATCH

The commercial sealing operations that began in the 16th century had a devastating effect on pinniped populations. Of the 36 species of pinnipeds, 36% are listed on the IUCN Red List, as follows:

- 2 Extinct
- 1 Critically endangered
- 2 Endangered
- 7 Vulnerable
- 1 Near threatened

New Zealand fur seal
*Arctocephalus forsteri*

Length of male up to 7¼ ft (2.2 m), female up to 5½ ft (1.7 m)

South American sea lion
*Otaria byronia*

Males can be up to three times larger than females

Pronounced mane on male

South African fur seal
*Arctocephalus pusillus*

Length of male up to 7 ft (2.1 m), female up to 5 ft (1.5 m)

Northern fur seal
*Callorhinus ursinus*

Male has massive, maned neck

Length of male up to 8 ft (2.5 m), female up to 6 ft (1.8 m)

Californian sea lion
*Zalophus californianus*

Short stubble on black flippers

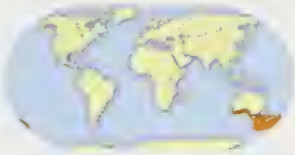
Largest of the eared seals

Steller's sea lion
*Eumetopias jubatus*

## FACT FILE

**New Zealand fur seal** In late spring, male fur seals establish territories on rocky shorelines, where they are joined by females for breeding. After the pups are born, the females visit the ocean to forage but the males stay put until the end of the breeding season

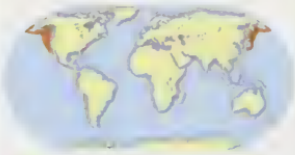
- Male up to 795 lb (360 kg) female up to 245 lb (110 kg)
- Harem
- Common



S.W. Australia to New Zealand

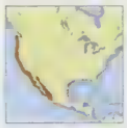
**Northern fur seal** These seals migrate south in winter, returning north to breed in spring. Some travel more than 6,000 miles (10,000 km) per year

- Male up to 605 lb (275 kg), female up to 110 lb (50 kg)
- Harem
- Vulnerable



North Pacific, Bering Sea

**Californian sea lion** The pinniped most often used in animal acts, this vocal, gregarious species sticks close to shore and frequently hauls itself onto land or structures such as jetties and piers



- Male up to 880 lb (400 kg), female up to 265 lb (120 kg)
- Harem
- Common, increasing

Coastal W. North America

## TERRITORIAL MALES

Eared seals tend to be highly so[illegible] will gather in large numbers during t[illegible] breeding season. Males defend [illegible] patch of shore and harem[illegible] against other males, using aggressive postures and barl[illegible] before resorting to actual fighting

## FACT FILE

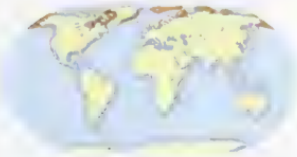
**Common seal** The most widely distributed pinniped, the common seal tends to be solitary but will gather in groups on land. A Canadian subspecies, the Ungava seal, lives in fresh water

- Male up to 330 lb (150 kg), female up to 245 lb (110 kg)
- Variable
- Common

North Atlantic, North Pacific

**Walrus** Walruses rely on a mustache of sensitive whiskers to locate their main food of clams and mussels, which they dig out of the sand with their snout The largest animal with the longest tusks usually dominates the herd

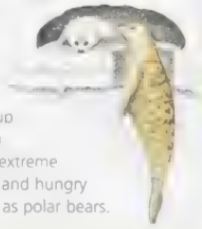
- Up to 11½ ft (3.5 m)
- Up to 3,640 lb (1,650 kg)
- Large herd
- Locally common



Shallow Arctic seas

### SNOW LAIRS

The ringed seal lives in waters that are covered in ice for at least part of the year. A pregnant female digs a cave into the snow above her breathing hole, which provides her pup with protection from both the extreme Arctic weather and hungry predators such as polar bears.

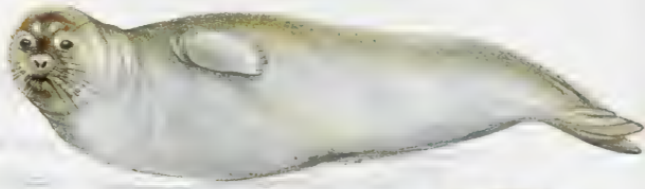


## CONSERVATION WATCH

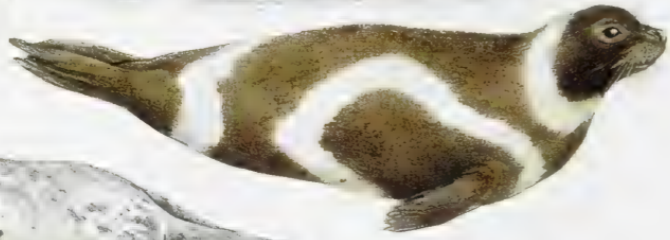
**Harp seal slaughter** In the late 1980s, a public outcry halted the clubbing of Canada's whitecoats, the very young pups of harp seals. Older pups have since been hunted throughout the Atlantic Ocean, however, often at levels that could precipitate a serious decline in overall numbers.

Bearded seal
*Erignathus barbatus*

Long, sensitive whiskers used to locate clams, snails, crabs, and shrimp



Baikal seal
*Phoca sibirica*



Ribbon seal
*Phoca fasciata*

Common seal (harbor seal)
*Phoca vitulina*

Length of male up to 6¼ ft (1.9 m), female up to 5½ ft (1.7 m)

Harp seal
*Phoca groenlandica*

White coats of pups shed by 3 weeks of age

Common name inspired by harp-shaped marking on back and sides of adult

Tusks on both males and females

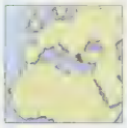
Walrus
*Odobenus rosmarus*

Ringed seal
*Phoca hispida*

Spots surrounded by ring of lighter fur

## FACT FILE

**Mediterranean monk seal** This species was once common throughout Mediterranean coastal waters, but an ever-growing human presence has seen its numbers dwindle. Today, its main refuges are small, barren islands

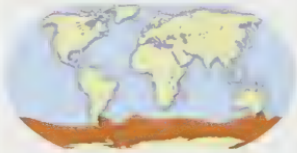


Up to 9 ft (2.8 m)
Up to 660 lb (300 kg)
Harem
Critically endangered

Coastal W. Africa, Aegean Sea

**Southern elephant seal** Males of this species can be more than six times heavier than the females. Only the largest 10 percent of males ever have the chance to mate. To attract females, a male inflates his trunk-like nose

Male up to 8,160 lb (3,700 kg), female up to 1,320 lb (600 kg)
Harem
Locally common



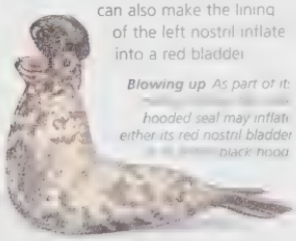
Argentina, New Zealand, sub-Antarctic islands

### KRILL EATERS

Rather than eating crabs as their name suggests, crabeater seals feed almost exclusively on the abundant supply of krill in Antarctic waters. They sieve the tiny crustaceans through their complex, knobbly cheek teeth.

### INFLATED NOSE

When it is trying to attract a mate, or is threatened or excited, mature male hooded seals have the unusual ability to blow up their black hood, which is an extension of the nasal cavity. They can also make the lining of the left nostril inflate into a red bladder



***Blowing up*** *As part of its [illegible] hooded seal may inflate either its red nostril bladder [illegible] black hood*

# THE RACCOON FAMILY

CLASS Mammalia
ORDER Carnivora
FAMILY Procyonidae
GENERA 6
SPECIES 19

Restricted to the New World, the family Procyonidae includes raccoons, coatis, kinkajous, ringtails, and olingos. All are medium-sized with a long body and tail, broad faces, and erect ears. Apart from the kinkajou, they also share mask-like markings on the face and alternating light and dark rings on the tail. Omnivorous feeding habits have enabled members of this family to thrive in habitats as varied as coniferous forest, tropical rain forest, wetlands, desert, farmland, and urban areas. Procyonids tend to be highly vocal, barking and squeaking to maintain complex social structures. Raccoons often sleep in communal dens, males may travel in groups, and females form "consortships" with one to four males. Male coatis are solitary, but bands of about 15 females groom one another, share the care of young, and fight off predators together. Kinkajous rest in groups of a female and her young plus two adult males.

**Opportunistic omnivores** Although their preferred habitat is woodland near water, raccoons have adapted to live alongside humans in rural and urban environments They often visit North American backyards to raid trash cans for food scraps, and may den in old buildings, cellars, or attics

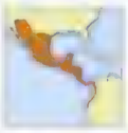
## FACT FILE

**Kinkajou** Originally classified as a lemur, the nocturnal kinkajou has a prehensile tail; large, forward-facing eyes; a primarily fruit-based diet; and a treetop lifestyle. It is nonetheless a carnivore, with genetic studies showing that it belongs in the Procyonidae family with raccoons and coatis

Up to 21½ in (55 cm)
Up to 22½ in (57 cm)
Up to 7 lb (3.2 kg)
Solitary, pair
Locally common

S. Mexico to Bolivia & Brazil

**White-nosed coati** Snuffling through the leaf litter on the forest floor by day, coatis use their flexible snouts and keen sense of smell to locate insect prey in crevices. They also consume large quantities of fruit and small vertebrates such as lizards and rodents. At night, they retreat to the treetops.



Up to 27 in (69 cm)
Up to 24½ in (62 cm)
Up to 10 lb (4.5 kg)
Family band
Locally common

Arizona to Colombia & Ecuador

**Raccoon** These nocturnal masked creatures eat whatever is available, from small vertebrates, insects, and worms to fruit, nuts, and seeds. They prefer aquatic prey, such as fish, crustaceans, and snails, which they appear to wash with their dextrous hands

[illegible]

Only New World carnivore with prehensile tail

Kinkajou
*Potos flavus*

Ringtail
*Bassariscus astutus*

Mobile tail used for balance

14–16 alternating black and white rings on tail

Raccoon
*Procyon lotor*

Forepaws are sensitive and dextrous

White-nosed coati
*Nasua narica*

## CONSERVATION WATCH

Of the 19 species of procyonids, 63% are listed on the IUCN Red List, as follows:

1 Extinct
7 Endangered
3 Near threatened
1 Data deficient

# HYENAS AND AARDWOLF

| | |
|---|---|
| CLASS | Mammalia |
| ORDER | Carnivora |
| FAMILY | Hyaenidae |
| GENERA | 3 |
| SPECIES | 4 |

The four species in the family Hyaenidae—the aardwolf and the brown, striped, and spotted hyenas—look rather like dogs but are classified as cat-like carnivores because they are more closely related to the cats and civets. Between their long front legs and shorter back legs, the spine distinctively slopes downward to the tail. A relatively massive head with a broad muzzle houses powerful, bone-crunching jaws and teeth. Unlike most other mammals, hyenas can digest skin and bone. They often scavenge the kills of lions and other predators, but sometimes capture their own prey. Spotted hyenas are the most effective hunters and will cooperate to bring down large prey such as zebra and wildebeest. The aardwolf is primarily an insect-eater, using its long, sticky tongue and peg-like teeth to harvest up to 200,000 termites per night.

**African distribution** The range of the striped hyena extends into the Middle East and South Asia, but the other Hyaenidae members are restricted to Africa. Hyenas and aardwolf are most often found in grassland or savanna habitats, where they take refuge in caves, thick vegetation, or abandoned burrows. Although no hyena species is endangered, they are often loathed and widely persecuted, and the spotted hyena depends on conservation measures for its survival

**Dominating females** Female spotted hyenas (*Crocuta crocuta*) are bigger than males, have large female genitals that look like a penis and scrotum, and outrank males in the clan. Mothers raise their young without any help from the father. When the cubs are a few months old, they join a communal den, where they remain until they are weaned at 15 months of age

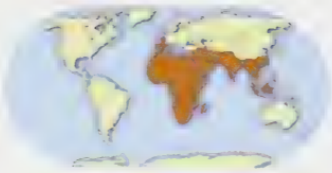
### CLAN SOCIETY

All hyenas live in clans of several or more animals that share a home range with spotted hyenas congregating in groups of up to 80 members. Elaborate scentmarking and greeting rituals help to maintain these complex social systems. When striped or brown hyenas meet, they erect their manes, sniff each other's head and body and may engage in ritual fighting.

# CIVETS AND MONGOOSES

CLASS Mammalia
ORDER Carnivora
FAMILIES 2
GENERA 38
SPECIES 75

The carnivore family Viverridae includes civets, genets, and linsangs. It also once included mongooses, but these have now been placed in their own family Herpestidae. Related to cats and hyenas, viverrids and herpestids tend to be medium-sized with a long neck and head, a long, slender body, and short legs. Their skeletal structure and teeth closely resemble those of the earliest carnivores, but the inner-ear region is highly developed. Viverrids are generally nocturnal, arboreal forest-dwellers with long tails, retractile claws, and erect, pointed ears. Many have scent glands near the genitals that in some species produce civet oil, once widely used as a perfume base. Mongooses tend to be found in more open country. Usually terrestrial and often diurnal, they have shorter tails, non-retractile claws, and small, rounded ears.



**Old World families** The civets, genets, and linsangs of Viverridae and the mongooses of Herpestidae are native to much of the Old World, with a number of species found only on the island of Madagascar. Famed as ratters, some mongooses have also been introduced on many islands in the New World, often with disastrous consequences. In the West Indies and Hawaii, for example, the introduced small Indian mongoose (*Herpestes javanicus*) is now a pest that attacks poultry and native fauna

## CONSERVATION WATCH

While a number of viverrids and mongooses are so successful that they are considered pests in areas, others are suffering as their habitat is destroyed. Deforestation is a critical issue on Madagascar, which has four endangered species from these families. Of the 75 species in Viverridae and Herpestidae, 32% are listed on the IUCN Red List, as follows:

- 1 Critically endangered
- 8 Endangered
- 9 Vulnerable
- 6 Data deficient

**Social life** While all viverrids and many herpestids usually live alone or in pairs, some mongoose species are gregarious and live in colonies. Suricates live in troops of up to 30 animals, which cooperate to care for the young and watch for danger. Nonbreeding members will babysit, and sentinel duties are rotated.

Coat pattern provides camouflage in dappled light of forest

Banded linsang
*Prionodon linsang*

Fanaloka
(Malagasy civet)
*Fossa fossana*

Fat reserves stored in tail for winter

Hose's palm civet
*Diplogale hose*

Falanouc
*Eupleres goudotii*

Owston's palm civet
*Chrotogale owstoni*

Banded palm civet
*Hemigalus derbyanus*

Differs from Owston's palm civet by lacking spots on the body

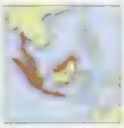
Black stripe along mane

Malayan civet
*Viverra tangalunga*

Banded collar

## FACT FILE

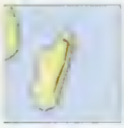
**Banded linsang** Sometimes called the tiger civet, this secretive forest animal sleeps in a vegetation-lined nest under a tree root or log. It mainly eats insects and small vertebrates such as squirrels, birds, and lizards.



Up to 17in (45cm)
Up to 14in (36cm)
Up to 2lb (1kg)
Solitary
Uncommon

Thailand, Malaya, Sumatra, Java, Borneo

**Fanaloka** The young of the fanaloka are born highly developed, with a full coat of fur and open eyes. They walk within a few days, eat meat after a month, and are weaned by 10 weeks.



Up to 17in (45cm)
Up to 8in (21cm)
Up to 4lb (2kg)
Pair
Vulnerable

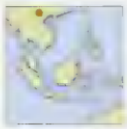
N. & E. Madagascar

**Falanouc** Like the fanaloka, this viverrid gives birth to precocial young who can follow the mother after only 2 days. It mostly eats insects and other invertebrates, building up fat deposits in its tail for the winter months when such prey are rare.

Up to 25in (65cm)
Up to 10in (26cm)
Up to 9lb (4kg)
Solitary, family band
Endangered

N. & E. Madagascar

**Owston's palm civet** This little-studied civet appears to be largely terrestrial, with earthworms featuring in its diet. Its striking coat may serve to warn predators of the foul-smelling scent produced by its anal glands.



Up to 28in (70cm)
Up to 16in (41cm)
Up to 8lb (4kg)
Solitary
Vulnerable

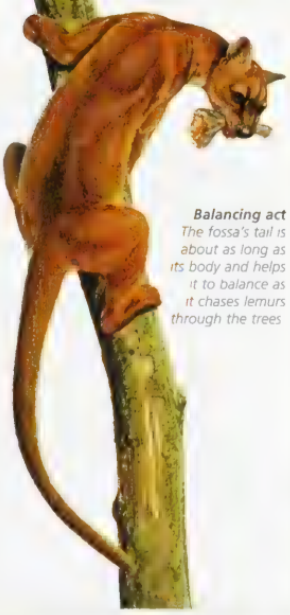
N. Vietnam, N. Laos, S. China

**Banded palm civet** Nocturnal and highly carnivorous, the banded palm civet spends the day sleeping in tree holes, emerging at night to hunt in the lowest floor. Its diet goes beyond ants, earthworms, fruits, and frogs.

[illegible]

## THE FOSSA

The dominant predator on the island of Madagascar is the fossa (*Cryptoprocta ferox*). This agile civet pursues lemurs through the trees, but will also hunt snakes, tenrecs, and guinea fowl on the ground. During the mating season, a female fossa waits high in a tree for males to congregate beneath her, then mates with a number of them for almost 3 hours



***Balancing act***
*The fossa's tail is about as long as its body and helps it to balance as it chases lemurs through the trees*

## MASKED MAMMAL

The masked palm civet of China and Southeast Asia plays a key role in its ecosystem. Through an omnivorous diet, it keeps insect and small vertebrate populations under control and helps disperse fruit seeds. In turn, it is a prey species of tigers, hawks, and leopards. To discourage predation, this civet relies on the powerful odor produced by its anal glands. Its distinctive facial markings may serve to warn predators of this noxious scent

Only viverrid with prehensile tail

Jerdon's palm civet
*Paradoxurus jerdoni*

Binturong
*Arctictis binturong*

Common palm civet (toddy cat)
*Paradoxurus hermaphroditus*

Brown palm civet
*Macrogalidia musschenbroekii*

African palm civet
*Nandinia binotata*

Masked palm civet
*Paguma larvata*

Three-striped palm civet
*Arctogalidia trivirgata*

Squirrels form part of civet's omnivorous diet which also includes frogs, birds, insects, and fruit

Narrow-striped mongoose
*Mungotictis decemlineata*

Ring-tailed mongoose
*Galidia elegans*

If threatened, bristles fur and arches back to increase apparent size

Large gray mongoose
*Herpestes ichneumon*

White-tailed mongoose
*Ichneumia albicauda*

Indian gray mongoose
*Herpestes edwardsii*

Stands upright to survey terrain for danger

Suricate (meerkat)
*Suricata suricatta*

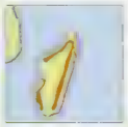
Yellow mongoose
*Cynictis penicillata*

Yellow coat in south of range, grayish in north

Banded mongoose
*Mungos mungo*

## FACT FILE

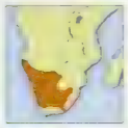
**Ring-tailed mongoose** Usually living in small groups of a pair and their young, this dainty mongoose spends the night in burrows. By day, it is equally at ease on the ground or in trees as it searches for lemurs, other small vertebrates, insects, and fruit



Up to 15 in (38 cm)
Up to 12 in (30 cm)
Up to 32 oz (900 g)
Solitary, pair
Vulnerable

Madagascar

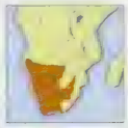
**Suricate** A sentinel suricate will give an alarm bark if it senses danger. The troop may attempt to outrun terrestrial predators such as jackals, but eagles, hawks, and other birds of prey send them fleeing to their burrow system



Up to 12¼ in (31 cm)
Up to 9½ in (24 cm)
Up to 33½ oz (950 g)
Family band
Locally common

S. Africa

**Yellow mongoose** This gregarious diurnal species lives in complex social groups of 8–20 animals based on a breeding pair, their young, and others. It often shares a burrow system with suricates and ground squirrels

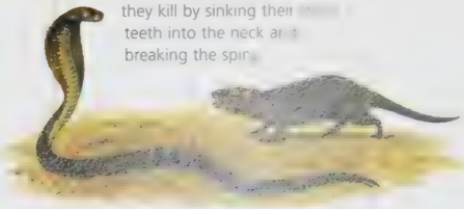


Up to 14 in (35 cm)
Up to 10 in (25 cm)
Up to 32 oz (900 g)
Family band
Locally common

S. Africa

## SNAKE ATTACK

Some mongoose species, including the Indian gray mongoose, are famed for their snake-killing ability. Although widely believed to be immune to the bites of cobras and other poisonous snakes, mongooses can tolerate only small amounts of the venom and must avoid being bitten. They rely on their speed and agility to conquer such dangerous prey, [illegible] they kill by sinking their [illegible] teeth into the neck and breaking the spine



*Standoff* [illegible]

# CATS

CLASS Mammalia
ORDER Carnivora
FAMILY Felidae
GENERA 18
SPECIES 36

The ultimate hunters, cats eat very little other than meat, making them the most carnivorous of the carnivores. Their predatory expertise has placed them at the top of many food chains on all continents except Australia and Antarctica and in habitats ranging from deserts to Arctic regions. Within the family Felidae, there are considerable size differences but few variations in general form. All species have a strong, muscular body; a blunt face with large, forward-facing eyes; sharp teeth and claws; and acute senses and quick reflexes. They generally rely on stealth to capture prey, which they stalk or ambush. Although largely terrestrial, cats are agile climbers and often good swimmers.

**Worldwide spread** Wild felids are the dominant predators on most continents, and are absent only from Australasia, Madagascar, Greenland, and Antarctica. First domesticated in ancient Egypt thousands of years ago, the domestic cat has since spread everywhere except Antarctica, and feral populations have had a serious impact on native ecosystems

**Surprise attack** Small cats such as bobcats, wildcats, and lynx tend to hunt smaller mammals such as rodents, lizards, and birds. They creep up, then suddenly pounce with a jack-in-the-box movement, killing the prey with a bite to the neck.

**Roars and purrs** A lion's roar usually advertises its control of territory. Only the big cats have a flexible-enough larynx to produce roars. All cats can purr, but big cats can purr only as they exhale, while small cats can produce a constant purr

***Open wide***
*Because they rarely eat vegetation, cats lack grinding teeth. Instead, their powerful jaws house blade-like teeth, with sharp stabbing canines and shearing carnassials. A rough tongue covered with tiny projections is used to rasp meat off bones and to groom the fur.*

## PRIME PREDATORS

Cats are split into three subfamilies: the big cats of Pantherinae include tigers, lions, leopards, and jaguars; the small cats of Felinae include pumas (which can be bigger than some "big cats"), lynx, bobcats, and ocelots; and cheetahs are on their own in Acinonychinae. The chief difference between the big and small cats lies in the flexibility of the larynx, which allows big cats to roar. Cheetahs are distinguished by their non-retractile claws and by their exceptional speed, which allows them to outrun fast prey such as gazelles over short distances.

The sense of smell is used for communication among cats, which scentmark their territory. When hunting, however, felids depend more on vision and sound. Forward-facing eyes provide binocular vision that helps with judging distances. A light-reflecting disk in the eye and rapidly adjusting irises enhance their night vision, which is up to six times sharper than that of humans. Large, mobile ears funnel sound to the sensitive inner ear, which can pick up the faint, high-pitched sounds of small prey such as mice.

The first felids began to evolve about 40 million years ago and led to today's species and to a branch that included the saber-toothed tiger, a massive creature with huge canines that disappeared only 10,000 years ago at the end of the last ice age. Cats were domesticated in the Middle East 7,000 years or so ago, a development that saw them spread to almost every part of the globe as companion animals.

### CONSERVATION WATCH

Because they need a wide range to find an adequate supply of prey, felids are particularly affected by habitat loss. Hunting has also taken a heavy toll on most cat species. Of the 36 species of felids, 69% are listed on the IUCN Red List, as follows:

1 Critically endangered
4 Endangered
12 Vulnerable
8 Near threatened

Lion
*Panthera leo*

Male is 30–50 percent heavier than female

Some males have dark mane, but most have golden mane

Lionesses do most of the hunting, but the male will usually eat first

"King" cheetah

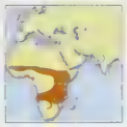
In some cheetahs, a recessive gene produces a blotchy coat pattern with stripes down the spine

Cheetah
*Acinonyx jubatus*

Cheetah cubs stay with mother until 13–20 months old

## FACT FILE

**Lion** While most felids tend to be solitary, lions are famed for their close enduring group relationships. Prides of 4–20 lionesses occupy a home range, cooperate to bring down large prey, and share care of the cubs. Males live alone or in coalitions with other males



Up to 7 ft (2.3 m)
Up to 39 in (1 m)
Up to 495 lb (225 kg)
Family band
Vulnerable

Sub-Saharan Africa, India

**Cheetah** With a burst of speed, the cheetah attempts to capture hoofed mammals such as Thomson's gazelle and wildebeest calves. Only about half such pursuits end in success. In turn, cheetahs are sometimes killed by lions

Up to 4½ ft (1.4 m)
Up to 31½ in (80 cm)
Up to 159 lb (72 kg)
Solitary
Vulnerable

Sub-Saharan Africa

## LION INFANTICIDE

The cubs in a pride of lions are usually sired by a coalition of two or three adult males. This resident coalition's tenure is usually short-lived, lasting only a few years before invading males move in. The intruders kill all the smaller cubs, which frees up the females to breed

***Protective mother*** *Lionesses carry their cubs in the mouth and will try to protect them from invading males*

## FAST AS A FLASH

Reaching speeds of 60 miles per hour (95 km/h) in pursuit of prey, the cheetah is the fastest mammal on land. Such sprints can last for only 20–60 seconds before the cheetah overheats and must rest. Sometimes it is too out of breath to defend its kill from a scavenger

## FACT FILE

**Tiger** The largest cats, these solitary hunters mainly rely on prey species much larger than themselves. They may travel 12 miles (20 km) in a day searching for food and need to kill a hooted mammal every 3–5 days to sustain themselves. Although tiger habitats are diverse, they all feature some form of dense vegetation that creates dappled light patterns. A tiger's striking stripes actually help it to blend into this background, allowing it to creep up on prey without being seen. Such camouflage is essential because a tiger cannot outrun its large prey and relies instead on the element of surprise. Even so, only about 5 percent of attacks succeed

India to E. Siberia
Former range

Up to 12 ft (3.6 m)
Up to 39 in (1 m)
Up to 795 lb (360 kg)
Solitary
Endangered

## VANISHING TIGERS

At the beginning of the 20th century, there were about 100,000 tigers roaming the tropical jungles, savanna, grasslands, mangrove swamps, deciduous woodlands, and snow-covered coniferous forests of Asia, from eastern Turkey to far eastern Russia. Today, perhaps fewer than 2,500 breeding adults remain in the wild. The Bali, Caspian, and Javan tigers—three of the eight tiger subspecies—are now extinct. Of the remaining subspecies, South China tigers exist only as a remnant population of 20–30 animals, and merely 500 or so Siberian or Amur tigers and 500 Sumatran tigers survive. The largest populations are of the Bengal tiger (shown at left) and the Indochinese tiger, but even these are in serious danger of extinction.

For years, tigers have been shot or poisoned because they are considered pests; because their skins as well as their body parts (used in traditional Asian medicine) fetch good prices; and because they are prized as trophies by sport hunters. At the same time, a continuing increase in local human populations has led to the degradation and fragmentation of much tiger habitat, as well as the decimation of hoofed mammals, the tiger's main prey, by subsistence hunters.

Although the tiger is now protected in most countries, illegal poaching persists. Conservation measures include preserving tiger habitat and reintroducing tigers in some areas.

Often rests in trees to avoid daytime heat or other predators

Leopard
*Panthera pardus*

"Black panthers" are in fact leopards with melanism, an excess of dark pigment

Clouded leopard
*Neofelis nebulosa*

Snow leopard
*Uncia uncia*

Jaguar
*Panthera onca*

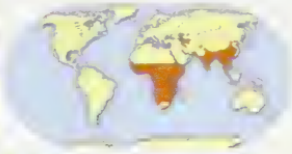
Stockier build and larger head and jaw than leopard

Largest cat in the New World

## FACT FILE

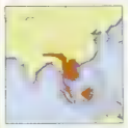
**Leopard** The most widespread big cat, the leopard owes its success to a varied diet, which includes gazelles, jackals, baboons, storks, rodents, reptiles, and fish. An agile climber, it often drags its kill to the safety of high branches

- Up to 7 ft (2.1 m)
- Up to 3½ ft (1.1 m)
- Up to 200 lb (90 kg)
- Solitary
- Locally common



Sub-Saharan & N. Africa; S., S.E. & C. Asia

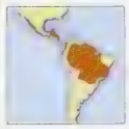
**Clouded leopard** This largely arboreal cat will wait in a tree to ambush prey such as deer and pigs below. It will also seize primates and birds in the branches. The species is the smallest of the big cats and has only a soft roar



- Up to 3½ ft (1.1 m)
- Up to 35½ in (90 cm)
- Up to 51 lb (23 kg)
- Solitary
- Vulnerable

Nepal to China, S.E. Asia

**Jaguar** This New World cat looks like the leopard, but fills a similar ecological niche to the tiger. It tends to live in dense vegetation near water and stalk large prey such as deer and peccaries It also takes fish and other aquatic prey



- Up to 6¼ ft (1.9 m)
- Up to 23½ in (60 cm)
- Up to 355 lb (160 kg)
- Solitary
- Near threatened

Mexico to Argentina

## SNOWED IN

Adapted to high altitudes, the snow leopard lives in the remote mountains of Central Asia. It has a dense coat with very large, furry paws that act as snowshoes. Up to five cubs are born in a rocky den lined with the mother's fur.

## FACT FILE

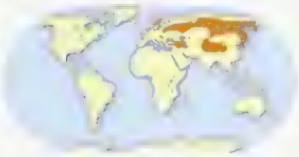
**Bobcat** Rare in some parts of its range but more common in others, the bobcat usually hunts small prey such as rabbits and rodents by night but will also eat carrion. It rests by day, often in a cave

Up to 41 in (105 cm)
Up to 8 in (20 cm)
Up to 68½ lb (31 kg)
Solitary
Locally common

Temperate North America to Mexico

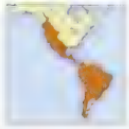
**Eurasian lynx** Mostly found in remote forested areas frequented by its main prey of small deer, this species remains active throughout the winter months.

Up to 4½ ft (1.3 m)
Up to 9½ in (24 cm)
Up to 84 lb (38 kg)
Solitary
Near threatened



France, Balkans, Iraq, Scandinavia to China

**Puma** This cat's once vast range is now largely restricted to remote mountains, where it hunts white-tailed deer, moose, and caribou. The puma hisses, growls, whistles, and purrs, but cannot roar.



Up to 5 ft (1.5 m)
Up to 38 in (96 cm)
Up to 265 lb (120 kg)
Solitary
Near threatened

Canada to S. Argentina & Chile

**Caracal** The swiftest of the small cats, the caracal can leap 10 feet (3 m) to snatch birds from the air. It also pounces on rodents and antelopes

Up to 36 in (92 cm)
Up to 12¼ in (31 cm)
Up to 42 lb (19 kg)
Solitary
Uncommon

Africa, Middle East, India & N.W. Pakistan

### JACKKNIFE CLAWS

Apart from the cheetah, all cats have retractile claws, which remain sharp because they are unsheathed only for capturing prey or climbing trees

Coat color and pattern vary according to location; most commonly reddish brown or grayish with spots on lower flanks or all over

African golden cat
*Profelis aurata*

Jungle cat
*Felis chaus*

Long legs for chasing prey

Pallas's cat
*Otocolobus manul*

Chinese desert cat
*Felis bieti*

Black-footed cat
*Felis nigripes*

European wildcats tend to have darker coats than those in Africa

Soles of feet are black and covered in hair that protects them from hot sand

Sand cat
*Felis margarita*

Wildcat
*Felis silvestris*

## FACT FILE

**Sand cat** This desert creature can survive in extremely arid conditions gaining enough water from its prey of rodents, hares, birds, and reptiles so that it does not need to drink

- Up to 21 in (54 cm)
- Up to 12½ in (31 cm)
- Up to 7½ lb (3.5 kg)
- Solitary
- Near threatened

Sahara Desert (N. Africa)

**Wildcat** This species looks like a large domestic tabby cat, but with a broader head and darker fur. A solitary creature, it hunts mainly at night for rodents, birds, small reptiles, and insects

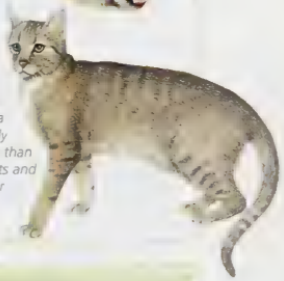
- Up to 29½ in (75 cm)
- Up to 14 in (35 cm)
- Up to 17½ lb (8 kg)
- Solitary
- Locally common

Africa, Europe to W. China & N.W. India

## FROM THE WILD

Cats were first domesticated in ancient Egypt when stores of grain attracted rats and mice to human settlements. The rats and mice drew wildcats, which were tolerated because they kept the rodents under control. The Romans spread domesticated cats throughout Europe. Today, there are more than 100 million domestic or feral cats in the United States alone.

***Wild feline*** *Although wildcats tend to be much more fierce than domestic cats, domestic cats retain the hunting instinct and readily revert to a feral state*



***African wildcat*** *Wildcats in Africa live in less densely wooded habitats than European wildcats and tend to be lighter in coat color*

## CONSERVATION WATCH

**Small cat status** Most small cats suffered drastic losses du[illegible] the 20th century. For some [illegible] as the pumas of Florida, fragmentation of habitat has isolated populations and led to inbreeding. The fur trade also had a [illegible] the ocelot and Ge[illegible] was gradually curta[illegible] became aware of the [illegible]

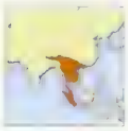
## FACT FILE

**Marbled cat** Resembling a smaller version of the clouded leopard, this highly arboreal species feeds mainly on birds. Hidden among the branches of dense tropical forests, it has rarely been seen and little is known of its behavior

Up to 21 in (53 cm)
Up to 21½ in (55 cm)
Up to 11 lb (5 kg)
Solitary
Vulnerable

Nepal, N.E. India, S.E. Asia

**Asiatic golden cat** This felid mostly preys on small mammals and birds, but will hunt in pairs to bring down larger quarry such as buffalo calves. Females give birth to one or two young in a den made in a hollow tree or among rocks. Unusually among cats, the male helps to raise the kittens



Up to 41 in (105 cm)
Up to 22 in (56 cm)
Up to 33 lb (15 kg)
Solitary
Vulnerable

Nepal to China, Indochina, Malaya, Sumatra

**Leopard cat** The swimming ability of the leopard cat may help to explain its presence on many islands in Asia. A subspecies, the Iriomote cat, is found only on the small Japanese islands of Iriomote and Ryukyu

Up to 42 in (107 cm)
Up to 17½ in (44 cm)
Up to 15½ lb (7 kg)
Solitary
Locally common

Pakistan & India to China, Korea & S.E. Asia

**Bay cat** This species is so rare that it was not photographed until 1998. It lives in jungles and among limestone outcrops near forests on the island of Borneo. The coat is most commonly chestnut red but can also be gray

Up to 26½ in (67 cm)
Up to 15½ in (39 cm)
Up to 9 lb (4 kg)
Solitary
[illegible]

[illegible]

**Fishing cat** This cat will tap the [illegible] surface to attract fish. It will [illegible] trees, then dive headfirst into water [illegible] aquatic prey [illegible]

Up to [illegible]
Up to [illegible]
[illegible]
[illegible]
Vulnerable

[illegible]

Elongated rather than rounded head

Coat can be chestnut or brownish gray

**Jaguarundi**
*Herpailurus yaguarondi*

**Oncilla**
*Leopardus tigrinus*

**Ocelot**
*Leopardus pardalis*

**Margay**
*Leopardis wiedii*

**Pampas cat**
*Oncifelis colocolo*

**Kodkod**
*Oncifelis guigna*

Geoffroy's cats have ocher coats in northern part of range, silvery gray coats in south

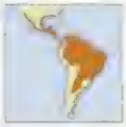
**Geoffroy's cat**
*Oncifelis geoffroyi*

Long, thick fur provides protection against exposed mountain environment

**Andean cat**
*Oreailurus jacobita*

## FACT FILE

**Jaguarundi** This species is not closely related to the other South American felids and does not look like a typical cat. Sometimes called the weasel cat or otter cat, its long, slender body, short legs, and very long tail do resemble those of a mustelid. The jaguarundi is an agile climber and good swimmer



Up to 25 in (65 cm)
Up to 24 in (61 cm)
Up to 20 lb (9 kg)
Solitary
Uncommon

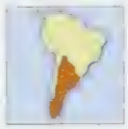
Arizona & Texas to S. Brazil & N. Argentina

**Ocelot** The wide variety of prey species taken by this opportunistic hunter has allowed it to live in a variety of densely covered habitats, from lush rain forests to semiarid brush. The ocelot's striking coat provides camouflage among thick vegetation, but has also made it a prime target for hunters. International trade in ocelot skins is now banned

Up to 18½ in (47 cm)
Up to 16 in (41 cm)
Up to 26½ lb (12 kg)
Solitary
Locally common

S.E. Texas to N. Argentina

**Geoffroy's cat** This agile cat can walk upside down along a branch and hang from a tree by its feet. Its populations were decimated by the fur trade, with more than 340,000 skins exported from Argentina between 1976 and 1979



Up to 26½ in (67 cm)
Up to 14½ in (37 cm)
Up to 13 lb (6 kg)
Solitary
Near threatened

S. Bolivia & Paraguay to Argentina & Chile

## FELINE DEFENSE

Cats of the same species try to avoid conflict by marking their territory with scent, but hostile encounters can occur. Small cats are also at risk from larger cats. When threatened, cats will use a series of body and tail positions and facial expressions in an effort to avert what could be a costly [illegible]

*Last warning*

# HUNTING STRATEGIES

While some carnivores are chiefly foragers, surviving on carrion, easily captured invertebrate prey, or vegetation, most hunt vertebrates at least some of the time and many are capable of taking down an animal much larger than themselves. Those that target small mammals, birds, and reptiles tend to hunt alone, while larger prey often, but not always, encourages cooperative efforts. Group hunting is most common among dogs, lions, and spotted hyenas, while raccoons, civets, mongooses, mustelids, brown and striped hyenas, and most cats are more likely to be solitary predators. Dogs kill small prey by shaking it in their jaws to dislocate the neck, and defeat larger prey by disemboweling it or seizing the throat or nose. Almost all cats sink their canine teeth into the neck of their victim, while weasels, civets, mongooses, and jaguars are occipital crunchers, biting into the back of the head so the claws and teeth of the prey are kept out of the way. The larger carnivores usually need to make a substantial kill every few days. To find enough to eat, these predators often roam over extensive home ranges, which vary in size according to the abundance of prey. Lions and tigers, for example, have ranges of 8–200 square miles (20–500 sq. km) and may cover up to 12 miles (20 km) in a day.

**Exception to the rule** Most large carnivores need to eat vertebrates to support themselves. While insects make easy prey, they are small and can usually sustain carnivores no larger than a badger or aardwolf. The sloth bear, however, is at least five times larger than a badger but manages to survive mostly on a diet of invertebrates. Its muscular limbs and long, curved claws enable it to rip open termite mounds, releasing thousands of insects at a time.

**Hyena variations** Brown and striped hyenas depend largely on carrion, supplemented by invertebrates and small prey. Consequently, they tend to forage alone, as group foraging offers little advantage and would lead to aggressive competition. The larger spotted hyenas depend more on hunting and pursue larger prey, such as zebra, wildebeest, gemsbok, and impala. When the prey is substantially larger than themselves, hyenas rely on cooperation to bring it down. Even when the prey is a young, smaller animal and a single hyena could complete the task alone, the kill supplies enough food to feed several hyenas, so pack hunting avoids waste.

***Family affair*** *Spotted hyenas may live in clans of up to 80 animals, but their hunting packs are smaller and tend to be made up of closely related individuals. This ensures that a successful hunt benefits relatives rather than unrelated hyenas.*

***Hot pursuit*** *Maintaining speeds of up to 35 miles per hour (60 km/h), hyenas will pursue their prey for up to 2 miles (3 km) until it tires and becomes vulnerable to attack. Only about a third of such pursuits end in success for the hyena pack.*

***The kill*** *Hyenas tend to focus on young, weak, sick, or injured hoofed mammals, which they separate from the herd. When the target prey falters, the pack members will simultaneously bite the belly to disembowel it*

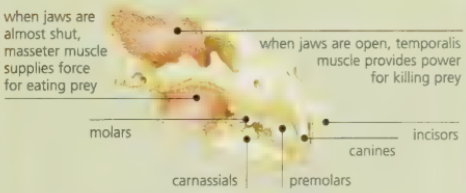
**Moving in** Even once a pack of spotted hyenas takes down an animal, they are not assured of a feast. Their main competitors are lions, which hunt the same prey and, attracted by the hyena's squabbling, may move in to steal the kill. While a pack of whooping hyenas advancing shoulder to shoulder may intimidate female or younger lions, they are no match for a male and usually surrender their meal.

***Fast eaters*** *If undisturbed, spotted hyenas will gorge themselves, eating up to a third of their weight in meat at a time. They often hide part of a carcass in muddy water for later consumption.*

***Making the most of a meal*** *When hyenas lose their kill to lions, they wait for the lions to finish eating and then return for the leftovers. A massive skull with a short, powerful jaw and immensely strong teeth allows hyenas to cut through the tough hides of their large prey and crush the bones to get to the marrow. Their acidic digestive system extracts all possible nutrition from the bones.*

**Success and failure** While predators are designed to outwit, outrun, or overpower their prey, the odds are not always in their favor. Most attempts at capture fail. The cheetah is capable of great bursts of speed in pursuit, but overheats in less than a minute and needs to rest. If the prey manages to stay ahead until this point, it will escape.

**A broad hunter** While some carnivores are highly specialized for capturing a particular kind of prey, others are generalists, pursuing any opportunity. The mink will hunt crustaceans and fish in water, take rabbits and birds on land, and chase small mammals down burrows. During times of scarcity, mink suffer from competition with more effective specialist predators, but can usually turn to an alternative source of food.




## MEAT-EATING TEETH

Carnivore jaws and teeth are uniquely adapted to a diet of meat. Jaws tend to be extremely strong, able to suffocate or crush the bones of prey even when the mouth is wide open, and providing enough force to cut through flesh. Typically, carnivores have 44 teeth, with 3 incisors, 1 canine, 4 premolars, and 3 molars on each side of each jaw. The last premolar in the upper jaw and the first molar in the lower jaw form the carnassials, sharp-tipped cusps that act like scissors to shear through meat. In carnivores that primarily eat insects or plants the equivalent teeth have flattened grinding surfaces but their ancestors possessed carnassials. In some carnivores, particularly the cat family, the canines are especially large and are used for stabbing p

# UNGULATES

CLASS Mammalia
ORDERS 7
FAMILIES 28
GENERA 139
SPECIES 329

Some 65 million years ago, an order of hoofed mammals known as Condylarthra began to evolve into many diverse orders, of which seven remain. These surviving orders are all now referred to as ungulates, meaning "provided with hoofs." In fact, only two orders possess true hoofs: odd-toed ungulates (Perissodactyla) include horses, tapirs, and rhinoceroses, while even-toed ungulates (Artiodactyla) encompass pigs, hippopotamuses, camels, deer, cattle, sheep, and goats. The other five orders, each with its own specializations, are elephants (Proboscidea), aardvark (Tubulidentata), hyraxes (Hyracoidea), dugong and manatees (Sirenia), and whales and dolphins (Cetacea).

**Mineral supplements** Mountain goats, deer, and other ungulates may all converge on particular mineral-rich salt licks. It is thought that licking the rocks supplies them with nutrients that are lacking from their otherwise herbivorous diet.

**Head of the harem** Like many other ungulates, zebras are territorial and live in harems of several mares dominated by a single stallion. The stallion will defend his harem from the attentions of other stallions by biting and kicking.

## HOOFS AND HERDS

Although less closely related to each other than to other members in the ungulate group, odd-toed and even-toed ungulates both stand on the tips of their toes, which are encased in hoofs. Together with their elongated metapodials (the hand and foot bones in humans), this unguligrade stance extends the leg, providing a longer stride and greater speed. As the dominant terrestrial herbivores, ungulates depend on their ability to run faster and farther than almost any large predator. They also have mobile ears, sharp, binocular vision, and a keen sense of smell to help them detect danger.

Another strategy for survival that is employed by many grassland ungulates is the formation of large herds. Living in a group increases the chance that a predator will be detected, and reduces any one individual's chance of being taken. Large herds are practical only on open plains, where many animals can remain in close contact. Many forest ungulates live in small family groups or are solitary.

Almost all ungulate species are herbivores, with teeth adapted for grinding. Their specialized digestive systems can break down cellulose, the usually indigestible component of plant cell walls. Food is fermented by microorganisms in the hindgut or in a special stomach chamber. Ruminants such as deer regurgitate the fermented food and chew it a second time, a practise known as "chewing the cud."

Elephants, hyraxes, and aardvarks lack true hoofs and do not have an unguligrade stance. While elephants have just the bones of their toes (encased in a fatty matrix) touching the ground, hyraxes and aardvarks walk on the entire foot.

Whales, dolphins, dugongs, and manatees have all evolved for life in the water, with a streamlined body and flippers. In fact, whales and dolphins were only recently classified as ungulates, when genetic studies showed that they are closely related to hippopotamuses. Some experts have even suggested placing them with even-toed ungulates in a single order called Certartiodactyla.

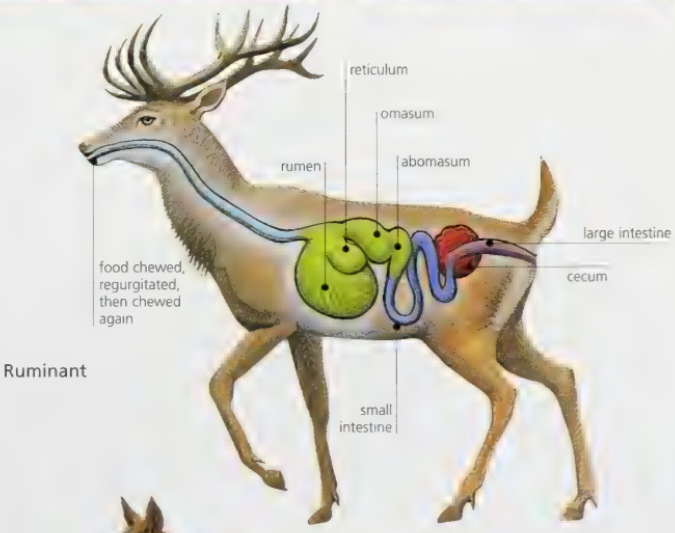
**Toes and hoofs** Elephants have a broad foot with five toes encased in a fatty matrix. In the "true" ungulates, at least one toe has been lost and the remaining toes form a hoof. The hoofs of odd-toed ungulates have three toes (as in the rhinoceros) or a single toe (as in the horse), while even-toed ungulates have two or four toes, which may be fused to form a cloven hoof (as in deer)

**Domestic ungulates** Sheep and goats were domesticated by 7500 BC, and cattle soon followed. In all, about 15 ungulate species have been domesticated and are now found worldwide. Their success, however, has devastated much of Earth's surface and has been at the cost of wild ungulates—for example, four livestock species now account for more than 90 percent of Africa's savanna ungulates

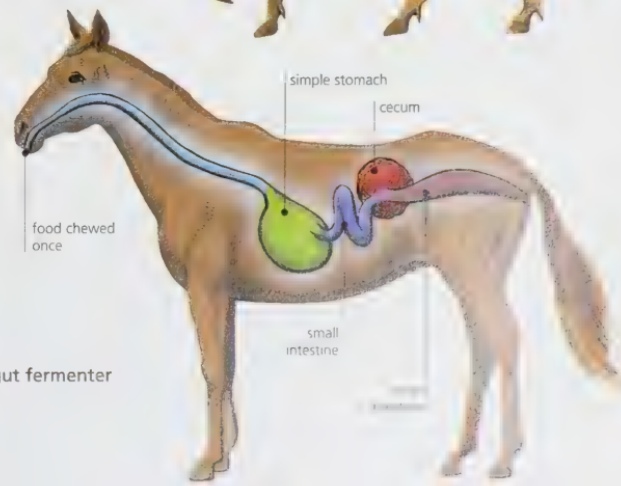
**Browsers and grazers** Ungulates may be browsers, feeding on woody vegetation such as trees and shrubs; grazers, feeding on grasses; or mixed feeders. African elephants concentrate on savanna grasses during the wet season, but switch to the woody parts of trees and shrubs when the grasses die back in the dry season.

**Advanced young** Although pigs have several piglets in a litter, most female hoofed mammals bear a single well-developed young, which can stand, see, and hear soon after birth. An impala will isolate herself to calve, but will rejoin the herd with her calf within a day or two.

**Fermenting stomachs** Ungulates rely on internal microorganisms to break down plant cellulose. Many even-toed ungulates, such as deer, cattle, and sheep, are ruminants. Their complex stomachs include a rumen, a chamber in which food is fermented by microorganisms before being regurgitated and chewed a second time. A ruminant's digestive process can take up to four days and gains maximum nutrition from food. Odd-toed ungulates, such as horses, rhinoceroses, and tapirs, ferment their food in the hindgut (the cecum and large intestine). The two-day digestive process is less efficient than that of ruminants, requiring odd-toed ungulates to consume greater quantities of food.




Ruminant




Hindgut fermenter

# ELEPHANTS

CLASS Mammalia
ORDER Proboscidea
FAMILY Elephantidae
GENERA 2
SPECIES 2

Weighing up to 7 tons (6.3 tonnes), elephants are the world's largest land animals. Their massive bulk is supported by four pillar-like legs and broad feet. An enormous head features immense fan-shaped ears and a long, flexible trunk. Full of blood vessels, the ears help to disperse the animal's body heat and will be flapped on hot days. The trunk, a union of the nose and upper lip, has more than 150,000 muscle bands and can both pick up twigs and lift heavy logs. Elephants can live for up to 70 years, longer than any land mammal apart from humans. As well as their longevity and strength, elephants are very social, intelligent, and quick to learn, traits that encouraged their domestication.

Asiatic elephant African elephant

**Flexible trunk** Used for caressing, lifting, feeding, dusting, smelling, as a snorkel, as a weapon, and in sound production, the elephant's trunk is superbly dextrous. Asiatic elephants have one finger-like projection at the tip, while African elephants have two

**Close relations** Female elephants usually bear a single young after a gestation period of 18–24 months—the longest of any mammal. The calf is weaned very gradually, and may continue to take milk from the mother for up to 10 years. Females remain with their mother's herd, while males leave at around 13 years

***Shared care*** *The female elephants in a herd share the care of the young and will form a circle around them to protect them from danger*

***Rapid growth*** *By the time it is 6 years old, a young elephant will weigh about 1 ton (1 tonne). Growth slows after about 15 years, but continues throughout its life*

**REMOVING THE THREAT**

While both elephant species are threatened by habitat loss, the African elephant's handsome tusks have also made it the prime target of the ivory trade. In an attempt to halt the trade, the Kenyan government burned piles of poached tusks (below) and the international sale of ivory was temporarily banned.

## MATRIARCHS AND MUSTH

The order Proboscidea appeared about 55 million years ago and once included immense mastodons and woolly mammoths. Its members inhabited all kinds of habitat, from polar regions to rain forest, and at some time lived on all continents apart from Australia and Antarctica. Today's elephants are restricted to the forests, savanna, grasslands, and deserts of Africa and Asia.

To fuel their immense bodies, elephants spend 18–20 hours a day foraging or traveling toward food. An adult may eat up to 330 pounds (150 kg) of vegetation and drink 40 gallons (160 l) of water per day.

The basic social unit of elephants is a family group of related females and offspring, led by a matriarch. Adult males visit these groups only to mate, spending the rest of their time alone or in bachelor bands. A number of family groups may form larger herds. To maintain their social ties, elephants rely on a range of communication methods, primarily using touch (greeting one another by intertwining trunks, for example), sound (some vocalizations are much lower than human ears can hear and travel up to 2½ miles, or 4 km), and postures (a raised trunk, for instance, can be used as a warning).

Mature male elephants have periods of musth, a time of high testosterone levels when the musth gland between the eye and ear secretes fluid. The animals become more aggressive and more likely to win fights, and wander greater distances in search of females.

Humped or level back

Asiatic elephant
*Elephas maximus*

Skin color often masked by the dirt the animal throws over itself or the mud in which it wallows

Tusks usually found only on males

Runs from danger with tail held up, possibly as a signal to fellow herd members

Tusks used to remove bark from trees, move fallen branches, mark trees, dig for water, and for fighting

Four nails on hindfoot

Heavier and taller than Asiatic elephant

Larger ears than Asiatic elephant

Concave back

Both males and females possess tusks

Trunk slightly floppier than that of Asiatic elephant

Young can follow mother a few days after birth

African elephant
*Loxodonta africana*

## FACT FILE

**Asiatic elephant** Smaller than the African elephant, this species is actually more closely related to the extinct woolly mammoth. The tusks are usually absent in the female. Females live in matriarchal herds of 8–40 mothers, daughters, and sisters. Males may spend much of their time alone or in temporary groups of up to seven males, but will join herds of females to mate Elephants are vocal communicators, using low-frequency calls to maintain contact over distance; high-frequency calls to convey their mood; and loud trumpeting calls to raise the alarm

Up to 21 ft (6.4 m)
Up to 10 ft (3 m)
Up to 6 tons (5.4 t)
Variable
Endangered

India to S.W. China, S.E. Asia

**African elephant** Occupying deserts, forests, river valleys, and marshes as well as savanna, this species survives mainly in protected areas. Poaching has led to a rapid decline in numbers, with the Kenyan population dropping from 167,000 in 1970 to 22,000 in 1989. In open habitat and especially during the wet season, herds may come together to form temporary aggregations of hundreds of individuals. Elephants that inhabit forests tend to be smaller in size and live in small family groups

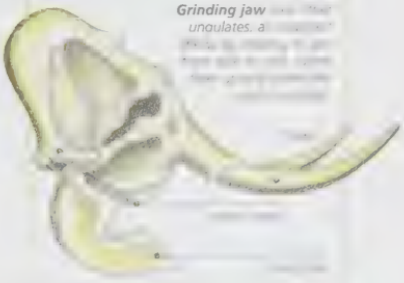
Up to 24½ ft (7.5 m)
Up to 13 ft (4 m)
Up to 7 tons (6.3 t)
Variable
Endangered

Sub-Saharan Africa

## INSIDE THE HEAD

The elephant's massive skull contains pockets of air to minimize its weight The tusks are elongated incisor teeth emerging from deep sockets. The molar teeth are replaced horizontally in a conveyor-belt fashion, with new teeth developing from behind and slowly moving forward to take the place of worn teeth

***Grinding jaw*** [illegible] *ungulates. a* [illegible]



# DUGONG AND MANATEES

CLASS Mammalia
ORDER Sirenia
FAMILIES 2
GENERA 3
SPECIES 5

Credited with inspiring the myth of the mermaid, the aquatic mammals of the order Sirenia are languid, docile creatures that never venture onto land. They are the only mammals to feed primarily on grasses and plants in shallow waters, a unique niche that may explain the order's lack of diversity, since seagrasses are much less varied than terrestrial grasses. The four living sirenian species are all found in the warm waters of tropical and subtropical regions. The dugong is restricted to the sea, while the Amazonian manatee is found only in the fresh waters of the Amazon River. African and Caribbean manatees live in freshwater, estuarine, and marine habitats.

**CONSERVATION WATCH**

The docile nature and delicious meat of sirenians have led to overhunting. The animals are now protected, but hunting continues illegally. All five species in Sirenia are listed on the IUCN Red List, as follows:

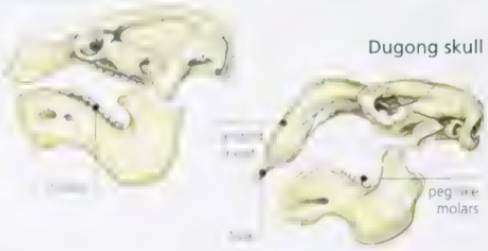
1 Extinct
4 Vulnerable

**Shaped for the water** The dugong has a streamlined body, with paddle-like flippers instead of front legs. Its tail is fluked like a dolphin's, whereas a manatee's tail is more like that of a beaver. While sirenians usually conserve energy by moving slowly through the water, they are capable of swimming swiftly to escape danger

**Bristled feeder** Like all sirenians, the Caribbean manatee swims slowly through the water, grazing on aquatic plants and seagrasses. It locates food with the aid of the sensitive, bristle-like hairs on its snout, and uses its muscular lips to grasp plants and pass them to the mouth

**Slow mothers** Sirenians have a very slow reproductive rate, which is a factor in their declining numbers. Females bear a single calf at a time, and wait at least 2 years and sometimes several before producing again. A calf nurses for up to 2 years, during which time it learns food sources and migration routes from its attentive mother

**Different skulls**




## GENTLE GRAZERS

Like other aquatic mammals, sirenians have a streamlined body, flippers, and flattened tail, and come to the surface to breathe through nostrils on top of the head. In keeping with a grazing lifestyle, the sirenian head is more like that of a pig and is used to root out grass rhizomes (underground stems) from the sediment. The angle of the dugong's snout restricts it to feeding from the bottom, but manatees can feed from all levels of the water.

The teeth of sirenians have become specialized in different ways for chewing great quantities of plant matter. The dugong uses rough horny pads in its mouth to crush its food, then grinds it with a few peg-like molars that continue to grow throughout its life. Manatees chew with their front molars, which are replaced by new teeth from behind when they wear out.

Sirenians have simple stomachs with extremely long intestines. Their plant food is broken down by microorganisms in the rear part of the digestive tract, making them hindgut fermenters like horses and other odd-toed ungulates. To counter the buoyancy provided by their gas-producing diet, sirenians have unusually dense, heavy bones.

Because their eyesight is generally poor, sirenians rely heavily on touch to find food. Their hearing is good underwater, with sounds transmitted through the skull and jaw bones. They emit squeaks to communicate, but how these sounds are produced is an enigma as they lack vocal cords.

Some sirenians live a solitary life, but more often, they are found in loosely structured groups of a dozen or so. Occasionally, such groups come together to form large herds of 100 or more. Social bonds are reinforced through playful nuzzling.

Because they have few natural predators, dugongs and manatees have developed no defenses other than their large size. This has made them easy targets for human hunters. Only about 130,000 individual sirenians remain, far fewer than in any other order of mammals.

## FACT FILE

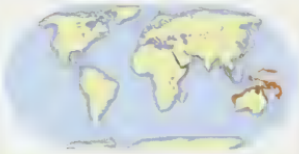
**African manatee** This poorly studied species is believed to be at least partly nocturnal. Found from coastal seas to rivers, it tends to feed from waters near or at the surface

- Up to 13 ft (4 m)
- Up to 1,100 lb (500 kg)
- Solitary, family group
- Vulnerable

W. African coast, Niger River

**Dugong** Now much reduced, the original range of this marine species coincided with the distribution of seagrasses, its main food. The dugong grazes mostly on the ocean floor

- Up to 13 ft (4 m)
- Up to 1,980 lb (900 kg)
- Variable
- Vulnerable



Red Sea to S.W. Pacific islands

**Caribbean manatee** This species moves freely between freshwater and marine habitats. When a female is ready to breed, a mating herd of up to 20 males will pursue her, competing for her attention for up to a month

- Up to 15 ft (4.5 m)
- Up to 1,320 lb (600 kg)
- Solitary
- Vulnerable

Georgia & Florida to Brazil; Orinoco River

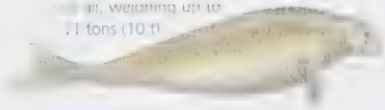
**Amazonian manatee** Few plants grow under the murky waters of the Amazon River, so this manatee feeds mainly on surface vegetation such as floating grasses and water hyacinths

- Up to 9 ft (2.8 m)
- Up to 1,100 lb (500 kg)
- Solitary

Amazon basin

### EXTINCT SEA COW

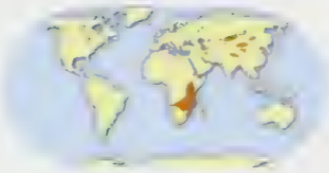
[illegible] Steller [illegible] weighing up to [illegible] tons (10 t)



# HORSES, ZEBRAS, AND ASSES

CLASS Mammalia
ORDER Perissodactyla
FAMILY Equidae
GENUS 1
SPECIES 9

The horses, zebras, and asses of the family Equidae rely on their large size, swift running style, and herding behavior to evade predation. An equid bears its weight on the tip of a single toe on each foot, a stance that provides a springy gait. The slender legs lock when at rest rather than relying on muscle contraction, a mechanism that minimizes the energy used during the many hours that the animal feeds. The teeth are highly specialized for a diet of grasses and other plants, with incisors to clip the vegetation, and complex, ridged cheek teeth for grinding. Plant cellulose is fermented in the hindgut, allowing equids to live on the abundant low-quality food of arid lands.



**Wild and feral** Wild equids live in grasslands, savanna, and deserts in Africa and Asia. They generally congregate in herds over large territories. Hunted for meat or hides and persecuted as competitors for grazing land, all wild equids have declined and most are at risk of extinction. Feral herds of the domestic horse can be found on every continent except Antarctica

## EVOLVING EQUIDS

All equids are covered in thick hair, with a mane along their long neck. Most species have single-colored coats, but zebras can be instantly recognized by their striking black and white stripes. Eyes at the side of the head provide good all-round vision by night and day, while erect, mobile ears with acute hearing listen out for danger. Equids tend to run away from predators, but will kick and bite to defend themselves if necessary. These highly social animals may whinny, bray, nicker, or squeal to communicate. Visual cues involving tail, ear, and mouth positions also play a role in equid communication, as does scent.

The first horse-like animal, a dog-sized mammal that walked on the soft pads of its feet, appeared about 54 million years ago. North America was the center of equid evolution, which resulted in a single-toed horse-like creature by at least 5 million years ago. Equids migrated to Africa and Asia, where modern species of zebras and asses later emerged. By the end of the last ice age, horses had vanished from North America, and were only reintroduced there by Europeans.

Humans first domesticated asses in the Middle East before 3000 BC, but within 500 years the faster and stronger domestic horse had arrived from Central Asia. Domestic horses revolutionized agriculture, transport, hunting, and warfare. Today, virtually all wild horses are feral populations of the domestic horse.

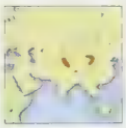
**Harem of horses** Wild horses, like common and mountain zebras, live in permanent groups of females and their young led by a harem male. The females are usually unrelated, having been abducted from their family group. Adult asses and Grevy's zebras form temporary associations

**The last wild horse** The domestic horse is descended from the tarpan (*Equus ferus*). The only tarpan to survive into the modern era is Przewalski's horse (*E. f. przewalskii*), a subspecies that once roamed Mongolia, but is now found only in zoos and a few reintroduced populations

**Grooming together** Both domestic and wild horses rely on mutual grooming to cement social bonds. Here, two foals nibble each other's shoulders and withers. The nose-to-tail stance allows them to continue to watch for predators

## FACT FILE

**Kiang** Herds of up to 400 mares and offspring are led by an old female Stallions usually live alone but several may live together during winter. In the summer mating season, stallions follow the large herds and fight one another for the right to mate.



Up to 8 ft (2.5 m)
Up to 4½ ft (1.4 m)
Up to 880 lb (400 kg)
Herd
Declining

Tibetan Plateau

**Onager** This wild ass is the fastest of the equids, reaching speeds of 40 miles per hour (70 km/h) in short bursts. It lives in arid environments, gathering in large, unstable herds with no lasting bonds between adults. Foals may be suckled for up to 18 months, but less than half survive their first year.

Up to 8 ft (2.5 m)
Up to 4½ ft (1.4 m)
Up to 575 lb (260 kg)
Herd
Rare

India, Iran; reintrod. in Turkmenistan

**Ass** In its wild form, the ass is rare, with only 3,000 individuals remaining. A surefooted animal, it was domesticated some 6,000 years ago and is still used as a beast of burden. The ass has great endurance and can survive for a long time in hot conditions with little food or water. Feral populations descended from domestic asses exist in several places. In the United States they are known as burros.

Up to 6½ ft (2 m)
Up to 4¼ ft (1.3 m)
Up to 550 lb (250 kg)
Harem
Critically endangered

Ethiopia, Eritrea, Somalia, Djibouti

## CONSERVATION WATCH

The quagga *Equus quagga*, a brown zebra, became extinct in the 1870s. The horse *Equus ferus* is classified as extinct in the wild, with the last true wild subspecies, Przewalski's horse, not seen in its natural habitat since 1968. Of the nine species of equids, six are listed on the IUCN Red List, as follows:

- 1 Extinct
- 1 Extinct in the wild
- 1 Critically endangered
- 2 Endangered
- 1 Vulnerable

## FACT FILE

**Zebra** [illegible] this equid [illegible] pattern of black stripes on [illegible] Suggestions that [illegible] camouflage or confuses predators have been discounted. The [illegible] explanation is that the stripes [illegible] role, possibly helping [illegible] identify each other.

## STRIPES AND MOODS

Like all equids, zebras use a range of visual signals to express their moods. Competing stallions will shake their head, arch their neck, and stamp their feet before resorting to physical contests in which they bite each other's neck and legs. Both mares and stallions will attempt to deter a predator with a kicking display.

***Prepared to bite***
[illegible]

***Ready to kick***
*A threatened equid will* [illegible]

***Getting a whiff***
[illegible]

# TAPIRS

**CLASS** Mammalia
**ORDER** Perissodactyla
**FAMILY** Tapiridae
**GENERA** 1
**SPECIES** 4

Appearing in the fossil record before either horses or rhinoceroses, tapirs as a group have changed little in the past 35 million years. These reclusive tropical-forest browsers are about the size of a donkey, with a squat, streamlined body for moving through the thick undergrowth, and a sensitive, prehensile trunk that is used for grasping food, detecting danger through scent, and as a snorkel. Tapirs emerge from the shelter of thickets at night to feed on the leaves, buds, twigs, and fruit of low-growing plants—by distributing seeds in their feces, they play an important ecological role in the forest. Being good swimmers and fond of water, they also consume aquatic vegetation. While their small eyes provide poor vision, the senses of hearing and smell are acute. Usually solitary and sparsely distributed, tapirs communicate through high-pitched whistles and scentmarking. Following a 13-month gestation period, a female tapir generally bears a single young. While the mother is foraging, a newborn will hide among the thickets, its patterned coat providing effective camouflage in the dappled light of the forest. After a week, it will accompany the mother, eventually going off on its own by the time it is 2 years of age.

**Reduced range** Found at various times throughout much of North America, Europe, and Asia, tapirs are now restricted to three species in Central and South America and a single species in Southeast Asia

**Water refuge** Never far from water, tapirs spend much of their time submerged, often with just the trunk appearing above the surface as a snorkel. Water provides cover from predators and relief from the heat

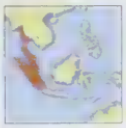
## FACT FILE

**Brazilian tapir** When this tapir plunges into water to escape a jaguar, it risks being taken by a crocodile. Its chief predator, however, is the human hunter, who follows its clear foraging trails

Up to 6½ ft (2 m)
Up to 3½ ft (1.1 m)
Up to 550 lb (250 kg)
Solitary
Vulnerable

Tropical South America (E. of Andes)

**Malayan tapir** This species is the only living tapir in Asia. Courtship is marked by whistling pairs walking around in circles as they attempt to sniff each other's genitals



Up to 8 ft (2.5 m
Up to 4 ft (1.2 m
Up to 705 lb (320 kg
Solitary
Vulnerabl

Myanmar, Thailand, Malaya [illegible]

## CONSERVATION WATCH

Tapir numbers are in decline as their forest habitat is lost or fragmented, they are hunted for the meat, and livestock compete for their food. All four species are listed on the IUCN Red List, as follows:

2 [illegible]
3 [illegible]

# RHINOCEROSES

CLASS Mammalia
ORDER Perissodactyla
FAMILY Rhinocerotidae
GENERA 4
SPECIES 5

The snout of a rhinoceros features its most distinguishing characteristic—a great horn or two made up of fibrous keratin. Rhinoceroses use their remarkable horns to fight rivals, to defend their young against predators, to guide their young, and to push dung into piles as scented signposts. Although keratin is a common substance that is also found in human fingernails, rhino horns are attributed great potency in traditional Asian medicine. Such has been the demand that many thousands of rhinoceroses have been poached, and all five species are now at risk of extinction. Today, there are fewer than 15,000 wild rhinos in Africa, and no more than 3,000 in Asia.

**High-speed charge** The third heaviest of all mammal species (after the African and Asiatic elephants), the white rhinoceros is still capable of impressive bursts of speed when charging to scare off intruders

**Rhino standoff** Both African rhino species use their horns to fight rivals, with fatal results. Bull rhinos use their pointy molars or canine teeth. Before resorting to physical attack, rhinos will engage in a period of gestures, including owning horn together, wiping horns on the ground, and scraping urine. Black rhinoceroses pictured here are especially aggressive, with horns on all males and a third of females doing after fights

***Sharp hearing*** Their ears pivot to pick up faint sounds

***Cropped horn*** To discourage poachers, the horn of this rhinoceros has been chopped

***Indian grazer*** A prehensile upper lip helps gather the grasses, but can be folded away for eating short grasses

***Dim sight*** Small eyes at the side of the head provide poor vision

**Armor plating** The Indian rhinoceros' distinctive dark gray skin has folds into deep folds at the joints, resembling the plates of a medieval armor. The rhinoceros's original Hindu name means "rhino-like one-horned one"

## CONSERVATION WATCH

Coupled with extensive habitat loss, the trade in rhino horns (used in Asia for medicine and carvings) has had a devastating effect. Some conservationists advocate farming rhinos and cropping their horns to provide revenue for the local people and thus discourage poaching. All five rhinoceros species are listed on the IUCN Red List, as follows:

- 3 Critically endangered
- 1 Endangered
- 1 Near threatened

## MASSIVE HERBIVORES

The family Rhinocerotidae was once abundant, widespread, and diverse. The woolly rhinoceros, for example, roamed Europe until the end of the last ice age 10,000 years ago and appears in early cave art. A hornless rhinoceros, *Indricotherium*, was the largest animal ever to have lived on land. Today, only five species remain, two in Africa (the white rhinoceros and the black rhinoceros) and three in Asia (the Indian, the Javan, and the Sumatran).

Rhinoceroses have massive bodies supported by four stumpy legs. Three hoofed toes on each foot leave an "ace-of-clubs" print in their tracks. Their thick, wrinkled skin can be gray or brown, but its true color is often masked by dried mud, since rhinos like to wallow in muddy pools. Despite their names, there is no clear distinction in skin color between white and black rhinos: both are grayish, with the precise tinge determined by local soil color.

With a lifespan of up to 50 years, rhinos are slow breeders, a fact that has made them especially vulnerable to habitat loss and overhunting. After a gestation of about 16 months, a female bears a single young and nurses it for more than a year. Their association lasts for 2–4 years, until the next calf is born. Most adult rhinos are solitary, but breeding pairs may stay together for a few months, while females or immature males sometimes form temporary herds. White rhinos are known to form a circle around the young to protect them from predators

Hump contains a ligament to support the massive head

White rhinoceros
*Ceratotherium simum*

Sumatran rhinoceros
*Dicerorhinus sumatrensis*

Two horns, with the longer in front

Prehensile lip for browsing on leaves

Name derived from Afrikaans word (*veit*) used to describe the rhino's wide mouth

Javan rhinoceros
*Rhinoceros sondaicus*

Indian rhinoceros
*Rhinoceros unicornus*

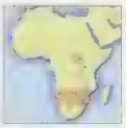
Calf can follow mother within a few days of birth

Black rhinoceros
*Diceros bicornis*

## FACT FILE

● Former range

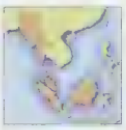
**White rhinoceros** The largest surviving rhino, this species has a long head and squared upper lip for efficient cropping of short grasses. Despite its size, the white rhino is usually a placid animal



Up to 14 ft (4.2 m)
Up to 6¼ ft (1.9 m)
Up to 4 tons (3.6 t)
Solitary, family group
Near threatened

Sub-Saharan Africa

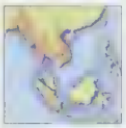
**Sumatran rhinoceros** The smallest of the rhinos, this is also one of the most threatened—only about 300 individuals survive in the wild. A browser that feeds mainly on saplings, it is the only Asian rhinoceros with two horns



Up to 10½ ft (3.2 m)
Up to 5 ft (1.5 m)
Up to 2¼ tons (2 t)
Solitary
Critically endangered

Thailand, Myanmar, Malaya, Sumatra, Borneo

**Javan rhinoceros** This one-horned rhino has heavily folded skin resembling that of its Indian neighbor. The future of this species is uncertain: only about 60 wild individuals remain and they are restricted to two national parks



Up to 10½ ft (3.2 m)
Up to 6 ft (1.8 m)
Up to 2¼ tons (2 t)
Solitary
Critically endangered

Vietnam, Java

**Indian rhinoceros** The larger of the one-horned rhinos, this species prefers to graze on tall grasses, but will also browse shrubs, crops, and aquatic plants. It avoids the daytime heat by foraging late or early, or at night

Up to 12½ ft (3.8 m)
Up to 6¼ ft (1.9 m)
Up to 2½ tons (2.2 t)
Solitary
Endangered

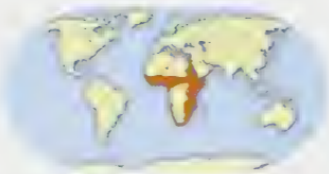
Nepal, N.E. India

**Black rhinoceros** This browser has a prehensile upper lip to draw branches into its mouth. More aggressive than the white rhino, the [illegible] charge humans and vehicles

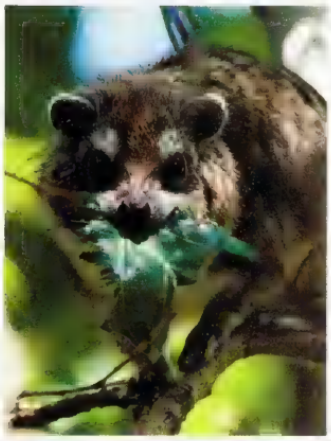
# HYRAXES

CLASS Mammalia
ORDER Hyracoidea
FAMILY Procaviidae
GENERA 3
SPECIES 7

About the size of a rabbit and looking rather like a large guinea pig, the hyraxes are often mistaken for rodents, but are in fact ungulates, with flattened hoof-like nails on their feet. Millions of years ago, hyraxes, some as large as tapirs, were the dominant grazing mammals of North Africa. They were displaced by larger ungulates such as antelopes and cattle. The surviving hyraxes are robust, agile creatures that scamper and leap along steep rocks and tree branches. The soles of their feet are uniquely equipped to provide traction, with soft pads kept moist by a glandular secretion, and muscles that retract the middle of the sole to form a suction pad. Hyraxes are gregarious animals, and some species live in colonies of up to 80 animals.



**Africa to the Middle East** Although they were once more diverse and widespread, hyraxes are now found only in Africa and the Middle East and there are just seven species in three genera. Rock hyraxes (*Procavia*) mostly live on rocky outcrops and cliffs in much of Africa and parts of the Middle East, but are also found in grassland and scrubby environments Yellow-spotted hyraxes (*Heterohyrax*) occupy similar habitats, but are largely confined to East Africa. Tree hyraxes (*Dendrohyrax*) also make Africa their home, but tend to live in forests



**Warm huddle** Most small mammals are nocturnal, but hyraxes are active by day Unable to regulate their body temperature well, they conserve heat by huddling together and warm up by basking in the sun. Hyraxes live in family groups of several females and their offspring, headed by a territorial male. Females usually stay with their family for life, but males disperse at about 2 years of age. They may live on the edge of a family group, hoping to take over the territorial male's position

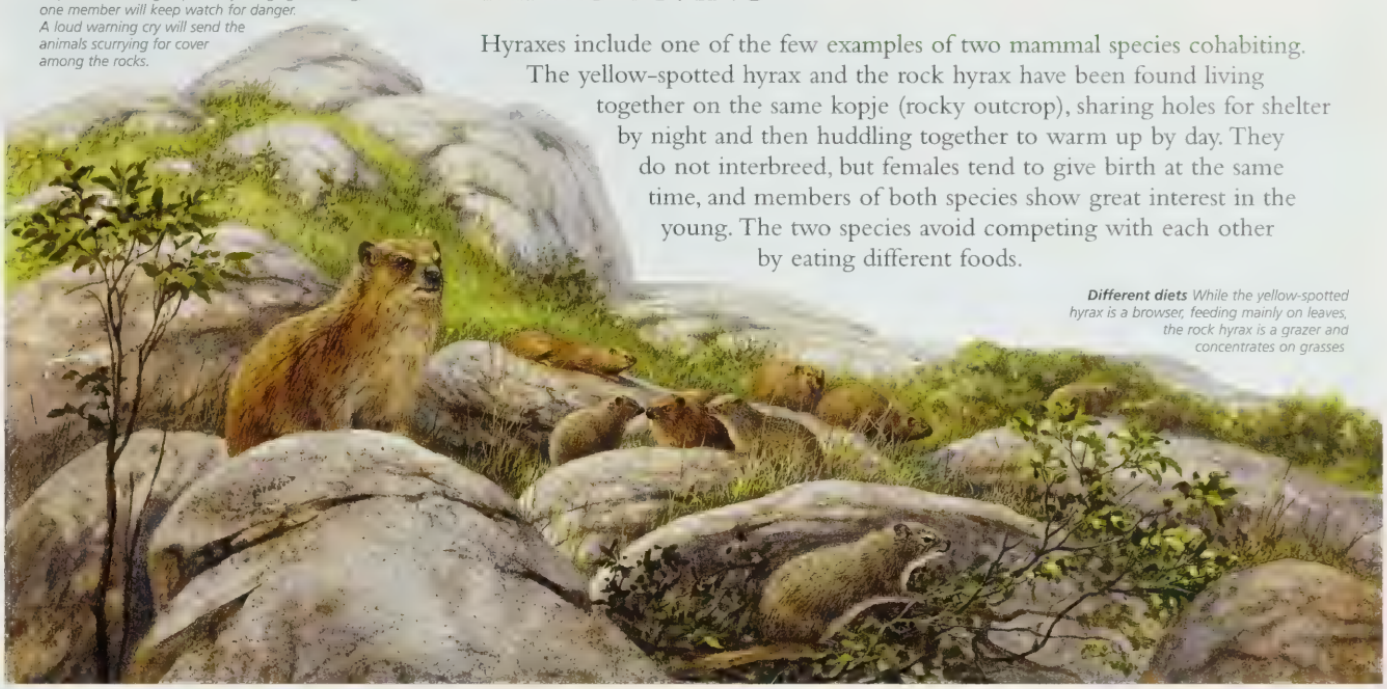
**Herbivorous hyraxes** All hyrax species will feed both in trees and on the ground, and have been known to travel almost a mile (1.3 km) in search of food. Rock hyraxes mainly eat grasses, while yellow-spotted hyraxes and tree hyraxes tend to browse leafy plants. They rely on microorganisms in their multichambered stomach to digest the plant cellulose Hyraxes are highly vocal creatures that sound like no other animal. The gregarious ground-dwellers chatter, whistle, and scream. At night, tree hyraxes begin a series of loud croaks that end in a scream [illegible] vocabulary changes and expands throughout life. Young hyraxes utter long [illegible] that progressively intensify, but [illegible] a fraction of the sounds [illegible] their adult relatives

## CONSERVATION WATCH

**Hunted pelts** Tree hyraxes are losing habitat as forests disappear. At least [illegible] the eastern tree hyrax ([illegible] *alidus*), is extensively [illegible] pelt. Of the seven [illegible] three are listed [illegible] just as vulnerable

## MIXED LIVING

Hyraxes include one of the few examples of two mammal species cohabiting. The yellow-spotted hyrax and the rock hyrax have been found living together on the same kopje (rocky outcrop), sharing holes for shelter by night and then huddling together to warm up by day. They do not interbreed, but females tend to give birth at the same time, and members of both species show great interest in the young. The two species avoid competing with each other by eating different foods.



***Standing guard*** *Hyraxes are prey for eagles, pythons, and leopards. While a group is busy foraging or resting, at least one member will keep watch for danger. A loud warning cry will send the animals scurrying for cover among the rocks.*

***Different diets*** *While the yellow-spotted hyrax is a browser, feeding mainly on leaves, the rock hyrax is a grazer and concentrates on grasses*

# AARDVARK

**CLASS** Mammalia
**ORDER** Tubulidentata
**FAMILY** Orycteropodidae
**GENERA** 1
**SPECIES** 1

A medium-sized pig-like animal with a stocky body, long snout, and large ears, the aardvark is the only living member of the order Tubulidentata, which evolved from an early hoofed mammal. Solitary and nocturnal, this highly specialized creature emerges from its burrow after dark to search for ants and termites, taking up to 50,000 insects a night. A keen sense of smell helps the aardvark to detect prey, while its powerful, clawed feet can excavate a termite mound in a few minutes. The hair-lined nostrils can be contracted and the ears folded back to keep out dirt. A long, sticky tongue snatches the insects, which are usually swallowed without chewing and ground up in the animal's muscular stomach. With its thick skin and sharp claws, an adult aardvark is vulnerable to few predators other than hyenas and humans.

### FACT FILE

**Aardvark** Aardvarks are most likely to be found near colonies of termites, their favorite food. Being nocturnal and shy, they are rarely seen in the wild

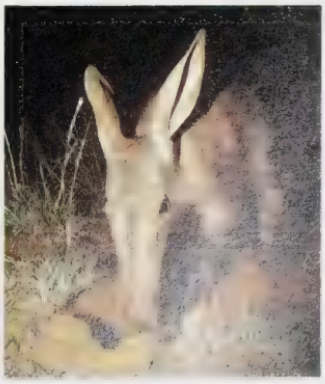
Up to 4 ft (1.2 m)
Up to 23½ in (60 cm)
Up to 154 lb (70 kg)
Solitary
Locally common

Sub-Saharan Africa

Aardvark
*Orycteropus afer*

### CONSERVATION WATCH

**Specialized ardvarks** Although the aardvark is not considered to be threatened, its highly specialized diet makes it vulnerable to habitat alteration. Grazing by both wild and domestic ungulates can benefit aardvarks, as termites flourish in the trampled ground. Crop farming, on the other hand, may cause a decline in aardvark numbers. Aardvarks are also hunted for their flesh.



**Determined digger** An aardvar[illegible] four shovel-sl[illegible] to dig out [illegible]

# THE CATTLE FAMILY

CLASS Mammalia
ORDER Artiodactyla
FAMILY Bovidae
GENERA 47
SPECIES 135

The family Bovidae includes many millions of domesticated cattle, sheep, goats, and water buffalo. The 135 species of wild bovid are much more diverse, ranging from the dwarf antelope, just 10 inches (25 cm) tall and weighing as little as 5 pounds (2 kg), to massive animals such as bison, which can be more than 6 feet (2 m) high at the shoulder and weigh up to 1 ton (1 tonne). Cattle and their kin occur naturally throughout much of Eurasia and North America, and introduced species have formed feral populations in Australasia, but bovids reach their greatest numbers and variety in the grasslands, savanna, and forests of Africa.

**Wide spread** Bovids are distributed from hot deserts and tropical forests to arctic and alpine regions. There are no native bovids in Australia or South America, but domestic species are found worldwide There are more than a billion domestic cattle in the world, and all are descended from aurochs, wild cattle that were once widespread but became extinct in 1627

**Safety in numbers** Cape buffalo usually live in herds of 50–500 females and young but thousands, including males, may congregate during the wet season. Weak buffalo can survive within a herd, which will cooperate to drive off predators

*Ringed horns*

*Two-tone*

**Ever alert** As prey species, bovids such as gazelles rely on their sharp senses to detect danger Most have large, mobile ears, eyes on the side of the head for all-round vision; and a keen nose. The striking coloration of many species may help to camouflage them by breaking up their outline

## A DIVERSE FAMILY

The cattle, buffalo, bison, antelopes, gazelles, sheep, goats, and other members of Bovidae are ruminants, with a four-chambered stomach for fermenting plant cellulose. This efficient digestive system has allowed bovids to make the most of low-nutrient foods such as grasses and colonize a wide array of habitats, from arid scrublands to arctic tundra. Grazing bovids tend to have a substantial, stocky build to house their large stomachs. Antelopes and other slender bovids are often more selective browsers.

All male and many female bovids have horns made up of a bony core covered in a layer of keratin, which is never shed. Always unbranched with pointed tips, bovid horns vary in size and can be straight, curved, or spiral. They may be used in contests between males or to fend off predators. The legs of bovids are adapted for running away from danger. Bovids bear their weight on the two middle toes of each foot, which form a cloven hoof. The main bones in the feet are fused to form the cannon bone, which helps to absorb the impact of running.

While some bovids are solitary or live in pairs, most are gregarious. Some species live in harems led by a male, while others have herds made up of females and young, with males being largely solitary or associating in bachelor herds. Group living not only reduces the risk of predation, but also allows members to share information about feeding sites.

Cattle and sheep were first domesticated several thousand years ago. Since then, most wild bovids have declined. Extensively hunted for food, hides, and sport, wild species have also lost much of their natural range to agriculture.

### CONSERVATION WATCH

Of the 135 species of bovids, 83% are listed on the IUCN Red List, as follows:

| | |
|---|---|
| 4 | Extinct |
| 2 | Extinct in the wild |
| 7 | Critically endangered |
| 20 | Endangered |
| 25 | Vulnerable |
| 37 | Conservation dependent |
| 19 | Near threatened |

Abbott's duiker
*Cephalophus spadix*

Yellow-backed duiker
*Cephalophus silvicultor*

Duiker species vary in size but share distinctive body shape

Red-flanked duiker
*Cephalophus rufilatus*

Large gland beneath each eye produces secretion used in scentmarking

Common duiker
*Sylvicapra grimmia*

Banded duiker (zebra duiker)
*Cephalophus zebra*

Short, conical horns

White band breaks up animal's outline

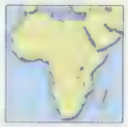
Ader's duiker
*Cephalophus adersi*

Ogilby's duiker
*Cephalophus ogilbyi*

## FACT FILE

**Duikers** Duikers are small, short-horned antelopes that browse at the forest edge, occasionally supplementing their diet with insects and small vertebrates. The name *duiker*—an Afrikaans word for "diver"—was inspired by this shy animal's habit of diving into the underbrush when frightened.

**Banded duiker** This muscular species is easily identified by the striking stripes of its coat. As in zebras, each banded duiker's pattern of stripes is unique. Banded duikers are diurnal creatures that usually live in pairs, with the pair bond reinforced by mutual grooming.



Up to 35½ in (90 cm)
Up to 19½ in (50 cm)
Up to 44 lb (20 kg)
Solitary, pair
Vulnerable

Liberia

**Common duiker** This nocturnal antelope lives at higher altitudes than any other African hoofed mammal. It relies on remarkable speed and stamina to escape its predators, which include big cats, dogs, baboons, pythons, crocodiles, and eagles.

Up to 45½ in (115 cm)
Up to 19½ in (50 cm)
Up to 46½ lb (21 kg)
Solitary
Common

Sub-Saharan Africa except rain-forest zone

**Ader's duiker** Active by day, this species tends to live in territorial pairs. It feeds mainly on flowers, fruit, and leaves from the forest floor, taking advantage of scraps discarded by monkeys and birds in the trees above. Like many other duikers, Ader's duiker has a soft, silky coat with a reddish crest on its head.

Up to 28½ in (72 cm)
Up to 12½ in (32 cm)
Up to 26½ lb (12 kg)
Solitary, pair
Endangered

Zanzibar, coastal S W Kenya

## CONSERVATION WATCH

**Dazzled prey** Prized by the bushmeat trade and as trophies, duikers make easy targets at night when they are dazzled by the lights of hunters. The IUCN Red List classifies a total of 16 duiker species as threatened. The rarest of these species is the endangered Ader's duiker, which has fewer than 1,400 individuals remaining in the wild.

## FACT FILE

**Lichtenstein's hartebeest** Males of this savanna species are territorial, marking their claim in the ground with their horns. Rivals will fight for the right to mate, with the victor leading a harem of 3–10 females and their young. Weaker males live alone or form loose bachelor bands.

Up to 7 ft (2.1 m)
Up to 4¼ ft (1.3 m)
Up to 375 lb (170 kg)
Small group
Conserv. dependent

S. Africa

**Hunter's hartebeest** One of the world's rarest mammals, this species declined from 14,000 to 300 animals in the wild between 1976 and 1995. A selective grazer, it eats only short, newly sprouting grasses and moves to another area if the grasses grow long or are disturbed by other grazers. Many scientists believe that Hunter's hartebeest represents the evolutionary link between true hartebeests and the genus *Damaliscus*, making its survival of the utmost importance to the study of antelope evolution.

Up to 6½ ft (2 m)
Up to 4¼ ft (1.3 m)
Up to 355 lb (160 kg)
Herd
Critically endangered

Kenya–Somalia border region

**Topi and tsessebe** These large grazing antelopes breed once a year, usually calving at the end of the dry season. In a large herd, the calves are likely to be followers, protected within a group of adults. In smaller herds, the calves may be hiders, concealed in dense vegetation while the adults forage.

Up to 8½ ft (2.6 m)
Up to 4 ft (1.2 m)
Up to 310 lb (140 kg)
Herd
Conserv. dependent

Savanna zone of sub-Saharan Africa

**Common hartebeest** With its sloping back, this large animal can appear awkward, but it is capable of reaching speeds of 50 miles per hour (80 km/h). It lives on open plains, preferring edge habitats near forest. Hartebeest may join other antelopes and zebras to form large aggregations.

Up to 6¼ ft (1.9 m)
Up to 4¼ ft (1.3 m)
Up to 330 lb (150 kg)
Herd
Conserv. dependent

Namibia to Botswana

Horns of a male gemsbok can be up to 5 feet (1.5 m) long

**Gemsbok**
*Oryx gazella*

Black-tufted tail

Dark markings on legs, flanks, and face

S-shaped, ridged horns only on male

**Impala**
*Aepyceros melampus*

Can leap up to 10 feet (3 m) off the ground

Scent glands beneath patches of black hair on rear feet

**Wildebeest**
*Connochaetes taurinus*

Vertical stripes of longer hair on back

**White-tailed gnu (black wildebeest)**
*Connochaetes gnou*

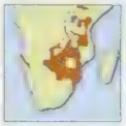
## FACT FILE

**Gemsbok** This species usually lives in herds of about 40 individuals, but hundreds may congregate during the wet season. During dry periods, the gemsbok can go without drinking for several days, surviving on the moisture content of fruit and roots.

Up to 5¼ ft (1.6 m)
Up to 4 ft (1.2 m)
Up to 530 lb (240 kg)
Herd
Conserv. dependent

E. & S.W. Africa

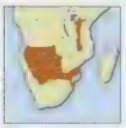
**Impala** Mainly a grazer during the wet season, when it feeds on lush new grasses, the impala switches to browsing woody plants in the dry season. When threatened, this animal usually attempts to outrun the danger but may also try to confuse a predator by leaping in random directions.



Up to 5 ft (1.5 m)
Up to 35½ in (90 cm)
Up to 110 lb (50 kg)
Herd
Conserv. dependent

Savanna zone of E. & S. Africa

**Wildebeest** Most wildebeest young are born within a single 3-week season, following a gestation of about 8 months. Within a few minutes of its birth, a calf can stand and nurse. About 40 minutes later, it can run.



Up to 7½ ft (2.3 m)
Up to 5 ft (1.5 m)
Up to 550 lb (250 kg)
Herd
Conserv. dependent

E. & S. Africa

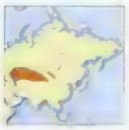
## RUTTING SEASON

During the mating season, which usually occurs at the end of the wet season, male impalas go into rut and will strongly defend their territory with scentmarking, defensive postures, and physical contests. Territoriality breaks down during the dry season, when impalas extend and overlap their ranges.

***A noisy display***
*The male impala's roaring display begins with a few explosive snorts, followed by several resonant deep grunts*

## FACT FILE

**Saiga** Apart from its ridged horns and the long, mobile nose that hangs over its mouth, this antelope resembles a small sheep. The breeding season takes a harsh toll on male saigas. Relying on stores of fat rather than grazing, males expend great energy defending their harem of several or more females against the attentions of other males. By the end of the season, up to 90 percent will have died in battle or from starvation or predation. Thousands of saigas may then form mixed herds to migrate to summer pastures.



Up to 4½ ft (1.4 m)
Up to 31½ in (80 cm)
Up to 152 lb (69 kg)
Herd
Critically endangered

Russia, Kazakhstan

## PRONKING

Gazelles sometimes leap repeatedly, keeping their back arched and legs stiff and landing on all fours—a habit known as "pronking" or "stotting." This behavior may occur when an animal is excited or alarmed and possibly distracts predators or warns them that they have been detected

***Leaping springbok***
*Named after its habit of pronking, the springbok erects the white crest on its back as it leaps up to 13 feet (4 m) in the air*

## CONSERVATION WATCH

**Dangerous horns** Prized in Chinese medicine as a cure for fevers, the horns of the male saiga are eagerly traded on the black market. Since the breakup of the Soviet Union in 1990, conservation measures have weakened and poaching has dramatically increased. Hunters target only males, so the surviving males are defending ever-larger harems and cannot impregnate all the females. Over the past 10 years the saiga numbers have declined by about 80 percent

Gerenuk
*Litocranius walleri*

Can stand on hindlimbs to browse on leaves that are out of reach of most antelopes

Beira antelope
*Dorcatragus megalotis*

Chiru
(Tibetan antelope)
*Pantholops hodgsonii*

Springbok
*Antidorcas marsupialis*

Blackbuck
*Antilope cervicapra*

Saiga
*Saiga tatarica*

Large, fleshy nose filters dust from air in summer and warms air in winter

Dibatag
*Ammodorcas clarkei*

## FACT FILE

**Steenbok** Exclusively a browser, this swift antelope prefers nutritious new growth such as young leaves, flowers, fruit, and shoots. It is the only bovid known to scrape the ground before and after urinating and defecating.

Up to 33½ in (85 cm)
Up to 19½ in (50 cm)
Up to 24½ lb (11 kg)
Solitary, pair
Common

E. & S. Africa

**Klipspringer** This sure-footed cliff dweller has a thick, moss-like coat that protects it from bumps and scrapes. It lives in small family groups in which one member acts as sentinel, giving a shrill whistle to warn of danger.

Up to 35½ in (90 cm)
Up to 23½ in (60 cm)
Up to 28½ lb (13 kg)
Pair, family band
Conserv. dependent

Mountain & rocky areas in E. & S. Africa

**Guenther's dik-dik** The long, mobile snout of this shy antelope is thought to help control the animal's temperature, with blood diverted to the snout being cooled before it travels to the brain.

Up to 25½ in (65 cm)
Up to 15 in (38 cm)
Up to 12 lb (5.5 kg)
Pair
Common

N.E. Africa

**Waterbuck** Old, weak herd animals are usually easy targets for predators. As a waterbuck ages, however, the secretions released by its sweat glands gradually impart an unpleasant taste to the flesh, encouraging predators to look elsewhere for a meal.

Up to 8 ft (2.4 m)
Up to 4½ ft (1.4 m)
Up to 660 lb (300 kg)
Herd
Conserv. dependent

Savanna zone of sub-Saharan Africa

**Mountain reedbuck** This species can breed at any time, taking advantage of favorable conditions whenever they occur. Like many antelopes and deer, it has a white patch under the tail that is displayed as it runs away from danger

Up to 4¼ ft (1.3 m)
Up to 28½ in (72 cm)
Up to 66 lb (30 kg)
Harem
Conserv. dependent

Mountains of C., E. & S. Africa

# MALE COMPETITION

During the breeding season, male gazelles will defend their territory and harem against challengers. Males mark their territory with secretions from the glands beneath each eye, as well as with urine and feces. Threat displays begin with the head raised so the horns lie along the back, and progress to the head tucked in with the horns vertical. Head lowered with horns pointed at the opponent is usually the last display before physical contact.

***Cushioned fights***
*Male gazelles sometimes have "air-cushion" fights, with the rivals charging at each other headfirst but stopping about 12 inches (30 cm) apart. If neither admits defeat after a series of such charges, physical fighting ensues.*

***Locking horns***
*Like other gazelles, sand gazelles fight by lowering the head, locking horns, and then twisting and pushing until one gives up and moves away.*

***Time out***
*Gazelles may interrupt a fight for a spot of feigned grazing before resuming the contest.*

***Dangerous games***
*While bachelor gazelles will practice their fighting skills in harmless sparring bouts, territorial males sometimes inflict serious injury.*

## FACT FILE

**Thomson's gazelle** With 90 percent of its diet consisting of grass, this species is almost exclusively a grazer. Thousands of individuals congregate for annual migrations, moving to woodland in the dry season and to grassland in the wet. Mature males establish territories, which are crossed by small, loosely structured groups of foraging females and offspring.

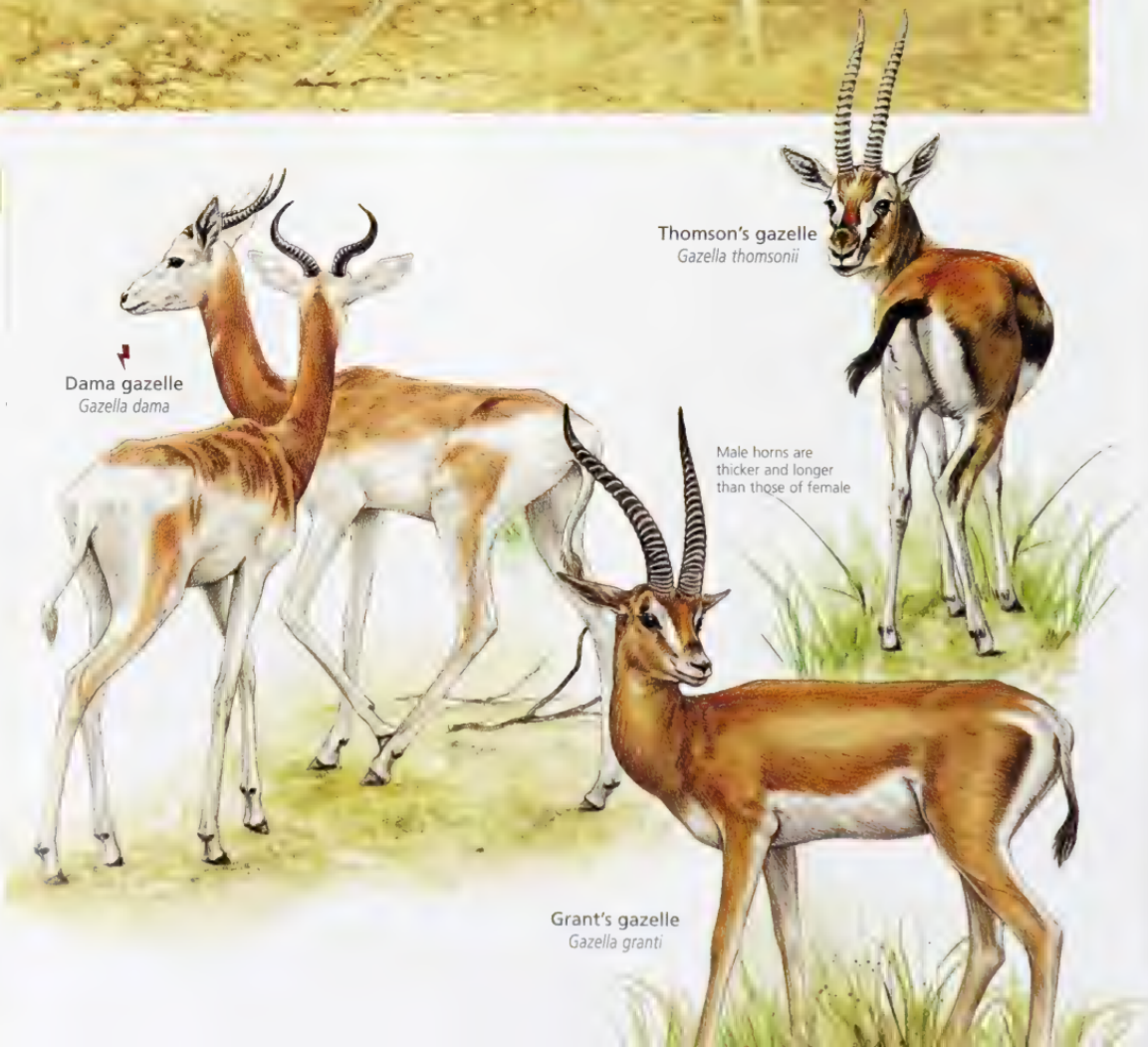
- Up to 3½ ft (1.1 m)
- Up to 25½ in (65 cm)
- Up to 55 lb (25 kg)
- Herd
- Conserv. dependent

E. Africa

**Grant's gazelle** This large species has a unique courting ritual in which the male makes sputtering sounds as he follows the female with his head and tail raised. Highly adapted to its hot, dry environment, Grant's gazelle can stand on its hindlimbs to reach moisture-rich leaves.

- Up to 5 ft (1.5 m)
- Up to 37½ in (95 cm)
- Up to 175 lb (80 kg)
- Herd
- Conserv. dependent

E. Africa



Spanish ibex
*Capra pyrenaica*

West Caucasian tur
*Capra caucasica*

Coat becomes redder in summer

Long outer coat protects warm, dense underfur

Mountain goat
*Oreamnos americanus*

Flexible hoof pads to grip uneven ground

Chamois
*Rupicapra rupicapra*

Takin
*Budorcas taxicolor*

Serow
*Capricornis sumatraensis*

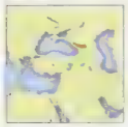
## FACT FILE

**Spanish ibex** Once abundant on the Iberian Peninsula, the Spanish ibex has suffered a dramatic decline in modern times, mainly because of overhunting. Fewer than 30,000 ibex remain and some subspecies are extinct.

- Up to 4½ ft (1.4 m)
- Up to 29½ in (75 cm)
- Up to 175 lb (80 kg)
- Herd
- Near threatened

Spain

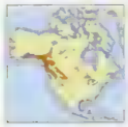
**West Caucasian tur** This high-altitude creature lives in stable groups of a few dozen animals, which sometimes form herds of up to 500 animals. It migrates to higher ground for a diet of grasses in summer, switching to tree and shrub foliage from lower slopes in winter.



- Up to 5¾ ft (1.7 m)
- Up to 3½ ft (1.1 m)
- Up to 220 lb (100 kg)
- Herd
- Endangered

W. Caucasus Mts

**Mountain goat** This animal can ascend rocky slopes with speed and agility as it searches for food such as grass, lichens, and woody plants.



- Up to 5¼ ft (1.6 m)
- Up to 4 ft (1.2 m)
- Up to 310 lb (140 kg)
- Family band
- Locally common

W. North America

## DEFENDERS AND GRAZERS

Sheep, goats, musk oxen, and their kin are collectively called goat-antelopes. They belong to the subfamily Caprinae, which first appeared in the tropics, but gradually moved into extreme locations such as deserts and mountains. Today's species range from resource defenders, such as serows, which live in productive habitats, to grazers, such as chamois, which tend to be gregarious, wide-ranging, and adapted to harsh conditions.

*Alpine* [illegible]

## FACT FILE

**Himalayan tahr** During the summer rutting season, competing males walk with their mane erect and head down to display their horns, with the stronger blocking the other's path or chasing it away. The contest rarely escalates to head wrestling

Up to 4½ ft (1.4 m)
Up to 3¼ ft (1 m)
Up to 220 lb (100 kg)
Herd
Vulnerable

Himalayas

**Nilgiri tahr** Vast herds of this species once roamed the grass-covered hills of southern India, but hunting and habitat loss reduced its numbers to only about 100 animals. As a result of conservation efforts, the total population has now risen to about 1,000 animals. The Nilgiri tahr has a coarse coat, with a short, bristly mane

Up to 4½ ft (1.4 m)
Up to 3¼ ft (1 m)
Up to 220 lb (100 kg)
Herd
Endangered

Nilgiri Mts (S. India)

**Markhor** This animal has suffered from excessive hunting and now survives only in fragmented populations in isolated, rugged terrain above the treeline. Its spiraling horns are prized both by trophy hunters and in Chinese medicine. Competition with domestic goats for food is also taking its toll

Up to 6 ft (1.8 m)
Up to 3½ ft (1.1 m)
Up to 245 lb (110 kg)
Herd
Endangered

Turkmenistan to Pakistan

**Saola** Until the 1990s, no new large mammal species had been scientifically described for decades. Then in 1992, the saola was discovered in Vietnam, a country where a protracted war and limited international contact had impeded study of its fauna. Considered one of the world's rarest mammals, the saola is a nocturnal, forest-dwelling ox found only in remote mountainous [illegible] travels in small groups of a few animals and appears to be [illegible] feeding on fig leaves and [illegible] forest vegetation.

Up to 6½ ft (2 m)
Up to 35½ in (90 cm)
Up to 220 lb (100 kg)
Solitary, family band
[illegible]

Male's horn size determines rank

Bighorn sheep
*Ovis canadensis*

Female horns have the same shape as male horns but are smaller

Aoudad (Barbary sheep)
*Ammotragus lervia*

Ventral mane of long white hair

Siberian bighorn sheep
*Ovis nivicola*

Dall sheep
*Ovis dalli*

Male horns almost meet at top of head in a "boss;" female horns are smaller with no boss

Musk ox
*Ovibos moschatus*

Long guard hairs can almost reach the ground

## FACT FILE

**Aoudad** Originating in the hills of the Sahara, the aoudad was introduced to Europe in the 1800s and to the southwest United States in the 1950s. Before mating takes place, the female aoudad licks the flanks of the male, and the pair may touch muzzles

Up to 5½ ft (1.7 m)
Up to 3½ ft (1.1 m)
Up to 320 lb (145 kg)
Herd
Vulnerable

N. Africa; introd. Europe & USA

**Bighorn sheep** To win the right to mate, male bighorn sheep will fight head to head, with contests sometimes lasting more than 24 hours. As well as their massive horns, which can weigh up to 30 pounds (14 kg), these sheep have a reinforced skull that is linked to the spine by a thick tendon

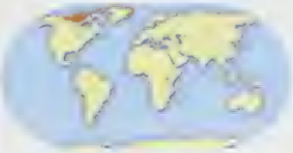
Up to 6 ft (1.8 m)
Up to 4 ft (1.2 m)
Up to 300 lb (135 kg)
Herd
Conserv. dependent

W. North America

## ARCTIC SURVIVORS

Musk oxen must survive long winters with subzero temperatures and little light. Their long guard hairs shield a dense underfur that is shed in spring. To reach grasses and sedges under the snow, musk oxen clear circular feeding patches with their horns and feet. A herd will crowd around a young musk ox to protect it from a predator

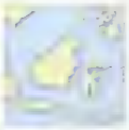
Up to 7½ ft (2.3 m)
Up to 5 ft (1.5 m)
Up to 905 lb (410 kg)
Herd
Uncommon



Arctic Canada & Alaska

## FACT FILE

**Anoa** [illegible]



**Bison** [illegible] 60 million bison, but the [illegible] females, offspring, and a few older males. Other mature males [illegible] live alone or form bachelor bands.

**Gaur** [illegible]

**Yak** [illegible]

## CONSERVATION WATCH

**Wild cattle and buffalo** Hunting, habitat loss, and domestic livestock (which interbreed with wild species, [illegible] diseases, and compete for [illegible]) have had a devastating effect [illegible] wild cattle and buffalo species. Today, most depend on protected [illegible] for their survival and a few, [illegible] the kouprey and tamaraw, [illegible] extinction. Conservation [illegible] have had some success, [illegible] with the wisent (European [illegible] declared extinct [illegible], but has since [illegible] from zoo stocks.

## BOVID HORNS

All bovids have hollow, unbranched horns made up of a layer of keratin surrounding a bony core. Unlike tusks horns leave the mouth free for grazing. Horns are sometimes used for defense, although bovids generally prefer to flee a predator if they can. The bovid species with the most elaborate horns are those that feature territorial or harem males, which must compete with one another in order to mate

***The most horns***
*The four-horned antelope is the only bovid with four horns*

***Greatest span***
*The African buffalo (Syncerus caffer) has a horn span of 50 inches (1.3 m)*

***Spiral design***
*The spiral shape of the kudu's horns helps them to lock during contests, preventing them from slipping and gouging the rival*

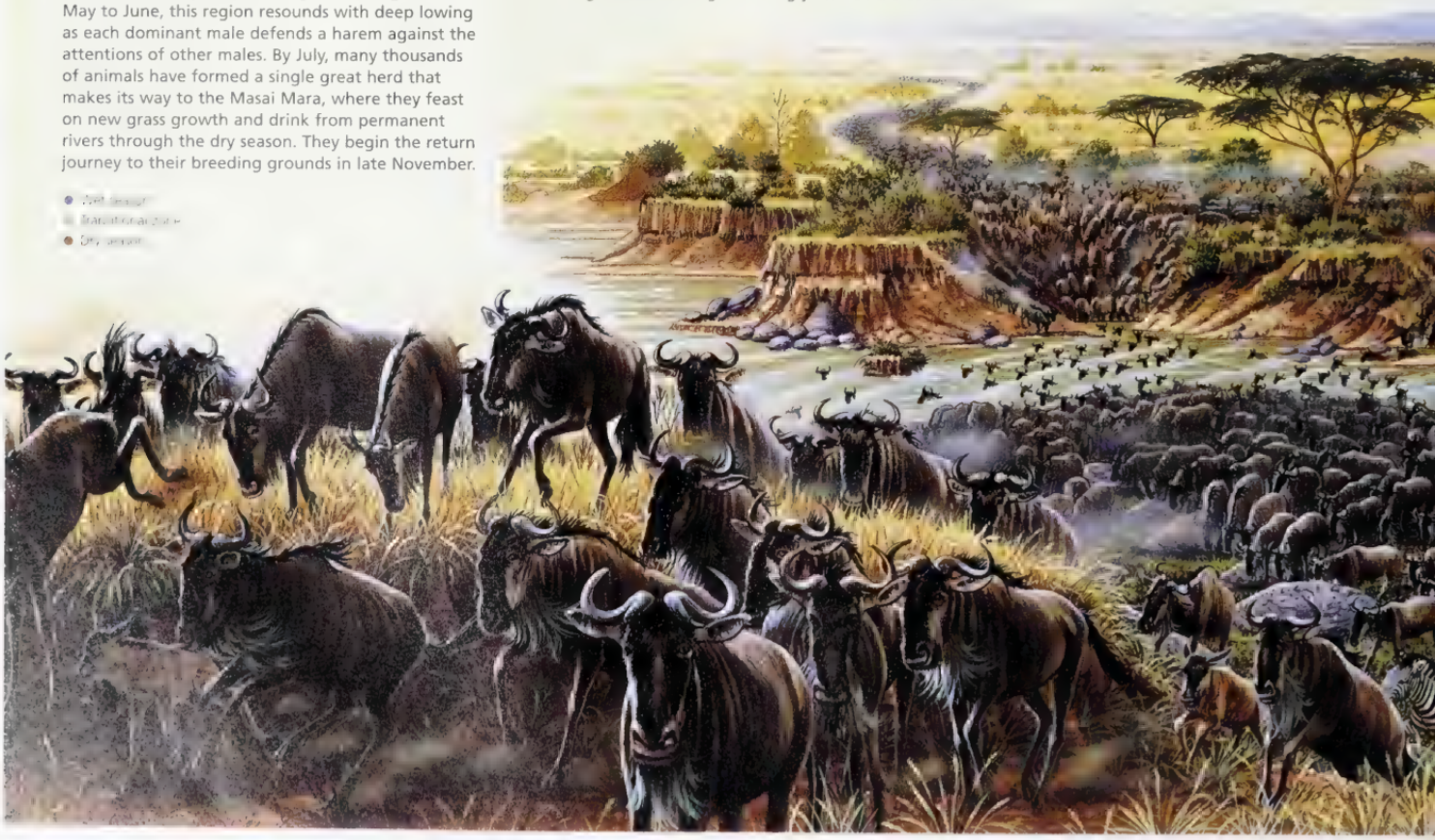
# INCREDIBLE JOURNEYS

Among the most astounding sights in nature are the seasonal migrations of large, hoofed grazers such as caribou in Canada and Alaska, gazelles in Mongolia, kob in southern Sudan, and wildebeest, zebras, and gazelles in East Africa. Migrating herds number in the thousands, and are prompted by changes in the weather to begin their mass movement. In colder climates, caribou and gazelles travel north to summer ranges, and south to winter ranges. In Africa, herd movement relates to the succession of wet and dry seasons. The greatest of all today's migrations is that of roughly 1.3 million wildebeest, accompanied by about 200,000 zebras and gazelles, from the Serengeti in Tanzania to the Masai Mara in Kenya—a clockwise route of more than 1,800 miles (2,900 km) per year. Some incredible journeys no longer take place, as ungulate numbers have dwindled and the land crossed by their migration routes has been developed. Hundreds of thousands of springbok once migrated over a vast range in southern Africa. In North America, as many as 4 million bison once traveled en masse through the Great Plains to reach the fresh grasses of their northern summer and southern winter ranges.

## MOVING CLOCKWISE

Early in the year, thousands of wildebeest give birth and then spread out on the plains of the Serengeti, which offer rain-ripened, mineral-rich short grasses. By the end of May, as the wet season comes to an end, these plains are depleted and the animals travel west and north in small groups to a transitional zone, where they mate. During the rutting season of May to June, this region resounds with deep lowing as each dominant male defends a harem against the attentions of other males. By July, many thousands of animals have formed a single great herd that makes its way to the Masai Mara, where they feast on new grass growth and drink from permanent rivers through the dry season. They begin the return journey to their breeding grounds in late November.

**River crossing** The most dangerous part of the great wildebeest migration is the crossing of the Mara River, which bisects the Masai Mara savanna. Swollen by the recent rains, the river can be a raging torrent. The migrating herd gathers at the banks until forced by the surge of animals to cross. Many wildebeest break their legs after leaping onto the rocky bottom. Others drown or are swept away by the powerful currents. Enormous crocodiles await, relying on the wildebeest prey for their main meal of the year. The animals that survive the crossing must then dodge the hungry lions on the other side.



**Swimming caribou** Each spring in Alaska and Canada, herds containing thousands of caribou migrate from their wintering grounds to their calving grounds farther north, traveling through deep snow and across icy rivers. After giving birth, the mothers feed on the tundra's nutritious new plant growth, which helps them produce rich milk. The calving grounds become cold and windswept as winter approaches, prompting the caribou to return south. In Europe, the same species has been domesticated and is known as the reindeer. The Sami herders follow the animals' natural migration routes.

**Winter herd** The world's largest remaining expanses of temperate grassland are found in eastern Mongolia. These steppes are home to the Mongolian gazelle (*Procapra gutturosa*). During summer, male and female gazelles form separate herds and females give birth. Large mixed herds of several thousand animals gather for the winter migration, covering up to 180 miles (300 km) a day until they reach their southern mating grounds. Overall numbers of the species appear to be in decline. The impact of fires, epidemics, and other natural disasters has been exacerbated by such disruptions to the gazelles' migration routes as fencing along the border with China and a new railroad in Mongolia.

***Annual cycle*** *The wildebeest mating season occurs in May to June. By the time of the perilous river crossing that occurs around July, more than 90 percent of all the adult female wildebeest may be pregnant.*

***Fellow travelers*** *Zebras travel with or ahead of the great wildebeest herd, grazing on the tough longer grasses and exposing the sweet new growth for the wildebeest. Gazelles tend to follow the wildebeest herd.*

***Survival of the fittest*** *Only the strongest members of the wildebeest herd make it from one side of the river to the other. They are rewarded by an abundance of lush green grass and spend their time building up reserves for the slow journey back to the Serengeti plains.*

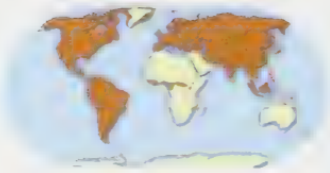
**Perilous journey** About 400,000 wildebeest are born every year in the Serengeti during a 6-week period beginning in late January. Of these calves, two out of three will perish on their first migration to the Masai Mara, but enough will survive to replenish East Africa's great wildebeest herds.

***Plenty for predators*** *The presence of the great herd in the Masai Mara attracts large numbers of predators. Crocodiles feast during the river crossing, while lions and hyenas target any stragglers.*

# DEER

CLASS Mammalia
ORDER Artiodactyla
FAMILIES 4
GENERA 21
SPECIES 51

The largest family in the deer group, Cervidae contains deer and their allies, including moose, caribou, and elk. In many ways, deer resemble antelopes, with long bodies and necks, slender legs, short tails, large eyes on the side of the head, and high-set ears. They are distinguished, however, by the often spectacular antlers borne by the males of most species (and also by female caribou). Unlike horns, which are permanent and made of keratin, antlers are made of bone and are shed once a year. Growing antlers are covered in skin known as "velvet," which dies and is rubbed off once the antlers reach full size. Antlers can be small, simple spikes or enormous, branched structures.



**Deer distribution** Deer never moved into sub-Saharan Africa, but they occur naturally in northwest Africa, Eurasia, and the Americas, and some have been introduced elsewhere. The species in the family Cervidae fall into two groups according to their ancestry: Old World deer first evolved in Asia, while the New World group began in the Arctic

**Lying up** Until they are strong enough to join the herd, newborn fawns such as this white deer spend their days hiding among vegetation. The newborn of many deer species have a dappled coat to break up their outline and provide camouflage. The mother visits regularly to suckle the fawn

**Northern habitats** Most deer are found in temperate or tropical forest, but some species have adapted to more extreme conditions. The moose might graze in northern wetlands, where its summer diet includes the roots of aquatic plants. The caribou lives on the treeless arctic tundra

## LARGE AND SMALL

The family Cervidae ranges from the southern pudu, weighing as little as 17½ pounds (8 kg), to the moose, at 1,760 pounds (800 kg). A moose's antlers can have a span of 6½ feet (2 m), though even these are dwarfed by the antlers of the extinct Irish elk (*Megaloceros*), which spanned 12 feet (3.5 m). One cervid species, the Chinese water deer, has no antlers at all, but its elongated canine teeth form knife-like tusks. Southeast Asia's muntjacs have only spikes for antlers but also bear tusks.

As prey species, deer have evolved various escape strategies. Some leap and dodge into a hiding spot. Others rely on great speed and stamina to outrun the threat. The moose can easily trot over obstacles that slow down its shorter predators.

All deer are ruminants with a four-chambered stomach, but, unlike bovids, they are not adapted to a diet of coarse grasses and rely on more easily digested food such as shoots, young leaves, new grasses, lichens, and fruit. Even those species that do graze on grasses need large amounts of high-quality browse as well.

The deer family is comprised of Cervidae and three other families of ungulates that superficially resemble them. These include the chevrotains of Tragulidae and the musk deer of Moschidae, which both have long canine teeth rather than antlers. North America's pronghorn is in its own family, Antilocapridae.

**Group grazers** While some smaller deer species live alone or in small family groups, larger species such as fallow deer tend to form herds. Living in a group offers a better chance of avoiding predation, as predators are more likely to be detected and tend to target only the weakest members. In New Zealand and other places, deer have been introduced and are bred commercially

Muscular hindlegs allow animal to perform agile jumps

Siberian musk deer
*Moschus moschiferus*

Like other members of the family Moschidae, this species lacks antlers but males have long canine teeth

Extensively hunted for musk produced by gland between navel and sex organs

Chinese water deer
*Hydropotes inermis*

Only species of Cervidae in which males lack antlers

Indian spotted chevrotain
(Indian mouse deer)
*Moschiola meminna*

Greater Malay chevrotain
*Tragulus napu*

Water chevrotain
*Hyemoschus aquaticus*

Lesser Malay chevrotain
*Tragulus javanicus*

Spotted and striped coat helps camouflage animal amid forest foliage

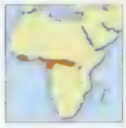
## FACT FILE

**Indian spotted chevrotain** The varied diet of this nocturnal animal includes both vegetation and small animals

Up to 24 in (60 cm)
Up to 12 in (30 cm)
Up to 6 lb (2.7 kg)
Solitary
Uncommon

India, Sri Lanka

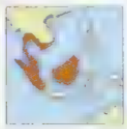
**Water chevrotain** Entirely nocturnal, this solitary animal hides in the dense undergrowth of the tropical forest by day. It usually lives near water and will enter water to avoid predators, but cannot swim for long periods.



Up to 37½ in (95 cm)
Up to 16 in (40 cm)
Up to 28½ lb (13 kg)
Solitary
Data deficient

Tropical W. Africa

**Greater Malay chevrotain** Because this species breeds at any time of year and will mate within a couple of hours of giving birth, females spend most of their life pregnant.



Up to 24 in (60 cm)
Up to 14 in (35 cm)
Up to 13 lb (6 kg)
Solitary
Uncommon

Indochina, Thailand to Malaya, Sumatra, Borneo

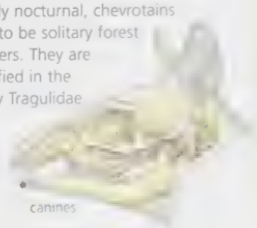
**Lesser Malay chevrotain** The smallest of all even-toed ungulates, this animal has legs about as thick as a pencil. It may live alone or in small family groups and feeds on fallen fruit and leaves.

Up to 19 in (48 cm)
Up to 8 in (20 cm)
Up to 4½ lb (2 kg)
Solitary, small group
Uncommon

Indochina, Thailand to Malaya & Indonesia

### CHEVROTAINS

Also known as mouse deer, chevrotains are small, even-toed ruminants, but unlike true deer and cattle they lack horns or antlers. The males have long, continually growing canines. Shy and usually nocturnal, chevrotains tend to be solitary forest dwellers. They are classified in the family Tragulidae



## FACT FILE

**Sambar** Native to Asia but introduced to Australia, New Zealand, and the [illegible] States, this nocturnal deer is most often found on forested hillsides. While several females with young may live together, males are usually solitary and aggressively defend their territories during the breeding season, when they mate with the females in their range.

- Up to 8 ft (2.5 m)
- Up to 5¼ ft (1.6 m)
- Up to 575 lb (260 kg)
- Solitary, harem
- Locally common

India & Sri Lanka to S. China & S.E. Asia

## IN A RUT

Known as wapiti or elk in North America and as red deer in Europe, *Cervus elaphus* is the noisiest of all deer species. After beginning courtship with a bugling call, males collect a harem, which they vigorously defend against other males throughout the rutting, or mating, season.

***Vocal assault*** *A harem male and his challenger [illegible] at each other [illegible]*

***Antler lock*** [illegible]

## CONSERVATION WATCH

Of the 51 species in the four "deer" families, 76% are listed on the IUCN Red List, as follows:

- 1 Extinct
- 1 Critically endangered
- [illegible] Endangered
- 11 Vulnerable
- [illegible] Near threatened
- [illegible] Data deficient

Antlers can be up to 3 feet (1 m) long

When tail is raised, the white underside acts as a "follow me" signal

**Sambar**
*Cervus unicolor*

**Barasingha**
*Cervus duvaucelii*

**Eld's deer**
*Cervus eldii*

**Rusa**
*Cervus timorensis*

Fawn is spotted for camouflage

**Roosevelt elk**
*Cervus elaphus roosevelti*

Critically endangered Chinese deer; disappeared from the wild around AD 200, but survived because a captive herd was maintained by the Chinese royal family and breeding pairs were reared in Europe; reintroduced into two Chinese national parks in the 1980s

**Père David's deer**
*Elaphurus davidianus*

**Mesopotamian fallow deer**
*Dama mesopotamica*

Palm-shaped antlers have numerous points

**Chital**
*Axis axis*

**Fallow deer**
*Dama dama*

**Philippine hog deer**
*Axis calamianensis*

**Tufted deer**
*Elaphodus cephalophus*

Tuft of hair hides male's antlers

**Giant muntjak**
*Megamuntiacus vuquangensis*

Tusk-like canine teeth on male

**Indian muntjak**
*Muntiacus muntjak*

## FACT FILE

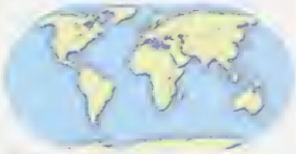
**Chital** This deer is mainly a grassland grazer, but will enter nearby forests to browse fallen fruit and leaves. Herds of females and young are followed by dominant males in the breeding season.

Up to 6 ft (1.8 m)
Up to 3¼ ft (1 m)
Up to 245 lb (110 kg)
Herd
Common

Sri Lanka, India, Nepal

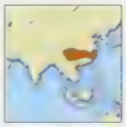
**Fallow deer** Most populations have been translocated from their natural range. Adaptable foragers, fallow deer have been introduced to diverse habitats, from the tropics to mountains.

Up to 6 ft (1.8 m)
Up to 3½ ft (1.1 m)
Up to 220 lb (100 kg)
Herd
Locally common



Originally Mediterranean to S.W. Asia

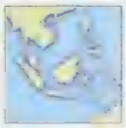
**Tufted deer** The male tufted deer has simple, spiked antlers and long, tusk-like upper canines. The antlers are often hidden by the hair on its forehead.



Up to 5¼ ft (1.6 m)
Up to 27½ in (70 cm)
Up to 110 lb (50 kg)
Solitary
Data deficient

E. Tibet & N. Myanmar to S.E. China

**Giant muntjak** First recorded in 1994, this secretive creature is about the size of a large dog, almost twice as big as the Indian muntjak.



Up to 3¼ ft (1 m)
Up to 27½ in (70 cm)
Up to 110 lb (50 kg)
Solitary
Not known

Vietnam

**Indian muntjak** Also called the barking deer, this species may bark for more than an hour if it senses a predator. It is omnivorous, using kicks of its forelimbs and bites to subdue small prey.

Up to 3¼ ft (1.1 m)
Up to 25½ in (65 cm)
Up to 61½ lb (28 kg)
Solitary
Uncommon

Sri Lanka, India, Nepal to S. China, S.E. Asia

## ANTLER CYCLE

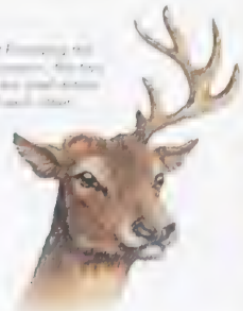
[illegible] used in contests between [illegible] deer, but the reason they grow so [illegible] appears to be that they advertise the male's healthy genes to females. In deer species with the largest antlers, much of the courtship routine involves elaborate antler displays.

***Spring***
In temperate [illegible] new antlers begin growing in late spring. They are covered in sensitive skin known as "velvet."

***Summer***
*By late summer, the antlers are fully grown and have hardened. The velvet begins to dry and loosen.*

***Fall***
*The male rubs the velvet off on shrubs and small trees. The antlers are now ready for the contests and displays of the mating season.*

***Winter*** [illegible]



Red brocket
*Mazama americana*

Both male and female bear horns, but the male's horns are longer and forked

Black markings only on male

Pronghorn
*Antilocapra americana*

Little red brocket
*Mazama rufina*

Peruvian guemal
*Hippocamelus antisensis*

Appears on Chile's coat of arms

Andean guemal
*Hippocamelus bisulcus*

Northern pudu
*Pudu mephistophiles*

Southern pudu
*Pudu puda*

Smallest of all deer in Cervidae family

## FACT FILE

**Red brocket** An elusive creature that most often lives in dense, tropical forest, this small deer can disappear into undergrowth or swim to escape predators. It lives alone or in pairs and feeds on fruit, leaves, and fungi

- Up to 5 ft (1.5 m)
- Up to 31½ in (80 cm)
- Up to 106 lb (48 kg)
- Solitary
- Data deficient

S. Mexico to N. Argentina

**Southern pudu** The smallest of all true deer species, the southern pudu will stand on its hindlegs to reach the leaves of trees or test the wind. Solitary except during the mating season, this territorial animal follows well-marked trails to its feeding and resting spots Listed as vulnerable, this species suffers predation from domestic dogs, and competition for food from introduced species such as fallow deer

- Up to 32½ in (83 cm)
- Up to 17 in (43 cm)
- Up to 28½ lb (13 kg)
- Solitary
- Vulnerable

S. Chile, S.W. Argentina

## THE PRONGHORN

The sole species classified in the family Antilocapridae, the pronghorn is able to reach speeds of 40 miles per hour (65 km/h), making it one of the fastest mammals on land. It is distinguished by its unusual forked horns, which are made from keratin surrounding a bony core, like the horns of antelope. As with the antlers of deer, however, the keratin is shed annually

- Up to 5 ft (1.5 m)
- Up to 3¼ ft (1 m)
- Up to 154 lb (70 kg)
- Herd
- Locally common

W. North America

***Unique horns*** *The head of a pronghorn buck features pronged horns, protruding eyes with long eyelashes, and a "mask" of black hair*

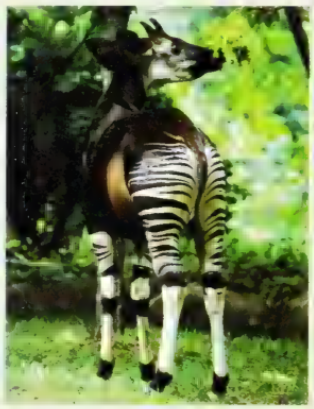
# GIRAFFE AND OKAPI

CLASS Mammalia
ORDER Artiodactyla
FAMILY Giraffidae
GENERA 2
SPECIES 2

With its head hovering up to 18 feet (5.5 m) above the ground, the giraffe is the tallest animal in the world. Along with its only close relative, the okapi, it is classified in the family Giraffidae. Both the giraffe and the okapi have a long neck, tail, and legs, with the forelimbs longer than the hindlimbs, creating a sloping back. Their small, constantly growing horns consist of bone covered by furred skin and are unique among mammals. The lips of giraffids are thin and mobile; the tongue is long, prehensile, and black; and the eyes and ears are large. Both species are found only in sub-Saharan Africa, where their strikingly patterned coats help them blend into their habitat—the giraffe's blotches mimic the dappled light of savanna woodland, while the okapi's rear stripes break up its outline amid the dense vegetation of the rain forest.

**Dangerous drinking** A giraffe gets most of the water it needs from its food, but will drink water when it is available. It must splay its forelegs to reach the water, making it vulnerable to predators at this time

**Necking rivals** To establish rank, young male giraffes engage in ritualized necking contests. Much like arm wrestles, these involve two giraffes intertwining necks and pushing each other until one gives way. Older male giraffes head-butt each other in an attempt to push over the opponent. Competing okapi bulls also neck-wrestle before progressing to more aggressive contact



### STRIPED BEHIND

The okapi was first described only in 1901, when a British explorer went in search of a horse-like animal hunted by the local people. At first glance, the okapi looks more like a zebra than a giraffe. It shares distinctive features with the giraffe, however, including unusual fur-covered horns, specialized teeth and tongue, and a ruminating, four-chambered stomach. The stripes on the rump probably act as a "follow me" signal and allow a young okapi to keep track of its mother. With the stripes on the forelimbs, they also break up the animal's outline amid the dense vegetation of the forest.

## DIFFERENT LIFESTYLES

Beyond their similarities, giraffes and okapi differ significantly. The most obvious contrast is in size and shape, with the okapi appearing rather horse-like, while the extreme elongation of the giraffe makes it instantly identifiable. The giraffe has only seven vertebrae in its neck, the same number as almost all other mammals, but each vertebra is lengthened. A specialized circulatory system powerfully pumps blood all the way up to its brain, but a series of valves adjusts the pressure when the animal leans down to drink.

The giraffe's extraordinary stature has allowed it to fully exploit the resources of its savanna woodland home. Because it is able to reach the leaves of tall acacia trees throughout the dry season, a giraffe can grow to a dramatic height and reproduce year-round. It is most vulnerable to lions and other predators when lying down or drinking. To avoid predation, a giraffe depends on its acute senses of vision, smell, and hearing. It may run away at speeds of more than 30 miles per hour (50 km/h) or deliver sharp kicks to the foe with its forefeet.

Living in dense, dark tropical forest, the okapi has poor vision but sharp hearing and a good sense of smell. It is extremely wary and will disappear into thick cover at the first hint of danger. Mostly solitary, this species marks its territory with urine or by rubbing its neck on trees.

The more open savanna habitat has encouraged giraffes to be social, and most live in small, loose herds of about a dozen animals. Young males may live in bachelor bands but tend to become solitary as they age. Males may fight each other for the right to mate, repeatedly swinging their long neck to deliver powerful head-butts to the rival's underbelly. A reinforced skull usually absorbs the impact of these blows, but occasionally an animal is knocked unconscious.

Horns on both males and females

Kenyan giraffe
*Giraffa camelopardalis tippelskirschi*

Southern giraffe
*Giraffa camelopardalis giraffa*

Short mane along neck

Long, tufted tail used to whisk away flies

Forelimbs longer than hindlimbs

Reticulated giraffe
*Giraffa camelopardalis reticulata*

Only males have horns

Okapi
*Okapia johnstoni*

## FACT FILE

**Giraffe** These gregarious animals most often live in loose, temporary herds of about a dozen cows and offspring led by an adult male. Able to survive for long periods without drinking and to forage from the high branches of acacia trees throughout the dry season, giraffes can breed at any time of year

Up to 18½ ft (5.7 m)
Up to 11½ ft (3.5 m)
Up to 1½ tons (1.4 t)
Variable
Conserv. dependent

Sub-Saharan Africa

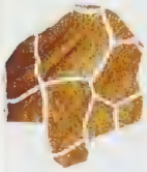
**Okapi** The okapi travels through the dense tropical forest along established paths by day, foraging for leaves, buds, and shoots. Apart from mother and offspring pairs, it lives alone. A single calf is born during the rainy season.

Up to 6½ ft (2 m)
Up to 5¼ ft (1.6 m)
Up to 550 lb (250 kg)
Solitary
Near threatened

N.E. Zaire

## IDENTIFYING MARKS

The blotched pattern on a giraffe's coat helps to camouflage the animal in the dappled light of the savanna woodlands. Each individual giraffe has a unique pattern, but broad similarities define the various subspecies.



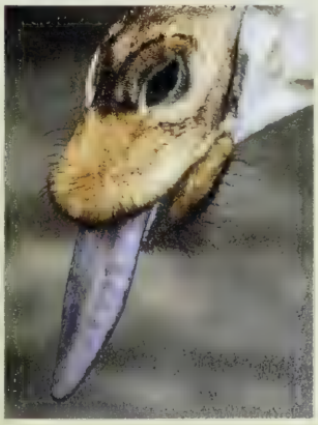
***Reticulated pattern***
*The reticulated giraffe has large, chestnut patches sharply separated by thin white lines*

***Kenyan contrast***
*Fuzzier, smaller, darker blotches separated by larger areas of white identify the Kenyan subspecies.*

## SPECIALIZED BROWSERS

The giraffe and the okapi are almost exclusively browsers. They both have thin, muscular lips and a long, black tongue that is dextrous enough to pluck foliage or pull branches to the mouth. The tongue of the giraffe (right) is especially long and can measure up to 18 inches (46 cm). Both species strip leaves from branches using their unique lobed canine teeth, and then grind them with their molars. A four-chambered, ruminating stomach helps them gain maximum nutrition from their food, which is regurgitated and chewed a second time. Unlike other ruminants, giraffes can walk as they chew the cud, allowing them to spend more time feeding. A giraffe may spend between 12 and 20 hours a day feeding, consuming up to 75 pounds (34 kg) of vegetation in that time.

Giraffes can cope with a wide variety in the quality of their food. They prefer new growth, flowers, and fruit, but are able to switch to twigs and dried leaves. Their staple diet is acacia trees, which have chemical defenses that make the leaves toxic and unpalatable. In response, giraffes carefully select the least toxic foliage to eat and have thick, sticky saliva and a specialized liver function. Both the giraffe and the okapi appear to supplement their diet with minerals from other sources: the giraffe eats soil and chews bones discarded by scavengers, while the okapi licks the clay of riverbanks and eats charcoal from burned trees.



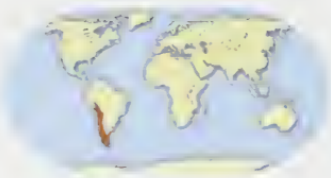
## CONSERVATION WATCH

**Red-listed** Both the giraffe and the okapi are listed on the IUCN Red List. With its natural range shrunk by about 50 percent, the giraffe is conservation dependent. [illegible] it feeds above the heads of [illegible] browsers, it has fared b[illegible] than many other native ung[illegible] The okapi is listed as [illegible] Despite being legally protected since 1933, the okapi is still hunted. Its highly localized distribution also makes it vulnerable to habitat loss.

# THE CAMEL FAMILY

CLASS Mammalia
ORDER Artiodactyla
FAMILY Camelidae
GENERA 3
SPECIES 6

Famed for their humps and the ability to survive for long periods without drinking, the two species of camel are the single-humped dromedary, now found only in domesticated populations in northern Africa and the Middle East, and the Bactrian camel, domesticated in northern Asia, but also found in small numbers in the wild. Their relatives in the family Camelidae are the four camelids of South America—the wild guanaco and vicuña, and the domesticated llama and alpaca. Camelids first appeared some 45 million years ago in North America, but disappeared from there about 10,000 years ago at the end of the ice age. By then, they had dispersed to other parts of the world.



**Old and new** The two Old World camels occur in northern Africa and central Asia The four South American species range from the foothills to the alpine meadows of the Andes Mountains. Domesticated camelids have been introduced in many places, including Australia, where feral dromedaries roam the central desert

**Precocious young** In all camelid species, a single, well-developed young is born after a long gestation period, which lasts 11 months in South America's guanaco. A newborn guanaco can follow the mother within about 30 minutes of its birth

## ROBUST CAMELIDS

All camelids are adapted to arid or semiarid regions. A complex, three-chambered ruminating stomach extracts maximum nutrition from their main food of grasses. Their feet are unique among hoofed mammals in that only the front of the hoof touches the ground, and the animal's weight rests instead on a fleshy sole-pad. In camels, the feet are broad, helping it to travel over soft sand without sinking. The four South American species have a narrower foot for walking securely up rocky slopes. A thick double coat insulates against both heat and cold.

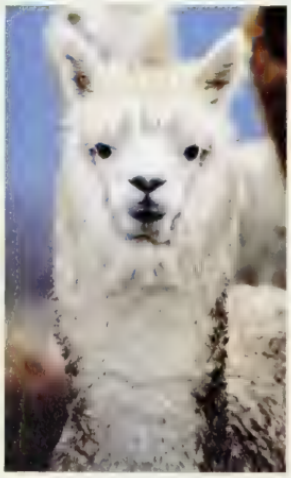
While Old World camelids are distinguished from the New World species by their much larger size and prominent humps, the overall anatomy is similar. All species have long, slender legs, a short tail, a long, curved neck, and a relatively small head with a split upper lip. When camelids walk, the front and back legs on the same side of the body move in unison, a distinctive gait known as pacing. Camelids are social animals and tend to live in harems of females and young led by a dominant male. Males without a harem may form bachelor bands.

By herding camelids, which provide meat, milk, wool, fuel, and transport, humans have been able to make a living in extreme locations, from the hot Sahara Desert to the cool high plains of the Andes. There are more than 20 million camelids in the world, but roughly 95 percent are domestic animals.

**Water wise** [illegible] duced [illegible] several [illegible] ls. [illegible] en water [illegible]

## DOMESTIC AND WILD

Until recently, both the domestic llama (right) and the domestic alpaca were assumed to be descendants of the wild guanaco. Molecular studies suggest, however, that the alpaca may be a cross between the llama and the wild vicuña. Both llamas and alpacas have been herded for many hundreds of years and there are now no wild individuals of these species. They vastly outnumber the wild guanaco and vicuña, but all South American camelids have been eclipsed by the introduced domestic sheep. Camelids were first domesticated in South America 4,000–5,000 years ago, and the llama was central to the success of the Inca Empire. Llamas and alpacas have now been introduced elsewhere, and are used for wool, to guard sheep, as pack animals for hikers, and as pets.



Fat stored in humps is used when food is scarce, causing humps to shrink

Bactrian camel
*Camelus bactrianus*

Long winter coat shed in summer

Narrow nostrils can close during dust storms

Long eyelashes keep desert dust out of eyes

Thick, tough lips can handle thorny vegetation

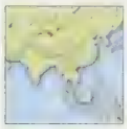
Dromedary
*Camelus dromedarius*

Guanaco
*Lama guanicoe*

Vicuña
*Vicugna vicugna*

## FACT FILE

**Bactrian camel** Along with the dromedary, this species is unique among mammals because its blood cells are oval rather than round. This shape may help the cells travel through thick, dehydrated blood.

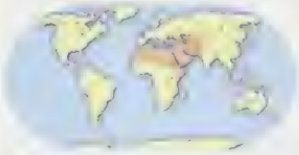


Up to 11½ ft (3.5 m)
Up to 7½ ft (2.3 m)
Up to 1,540 lb (700 kg)
Herd
Critically endangered

Kazakhstan to Mongolia

**Dromedary** Although domesticated, many dromedary herds are unattended during the mating season, when they revert to living in harems.

Up to 11½ ft (3.5 m)
Up to 7½ ft (2.3 m)
Up to 1,430 lb (650 kg)
Herd
Extinct in wild: domestic & feral only



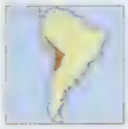
N. Africa to India; introd. Australia

**Guanaco** Male guanacos, like all male South American camelids, have some sharp, hooked teeth that are used as weapons during fights with rival males.

Up to 6½ ft (2 m)
Up to 4 ft (1.2 m)
Up to 265 lb (120 kg)
Family band
Locally common

S. Peru to E. Argentina & Tierra del Fuego

**Vicuña** Strictly a grazer, this small camelid has sharp, constantly growing incisors for snipping short grasses.



Up to 6¼ ft (1.9 m)
Up to 3½ ft (1.1 m)
Up to 143 lb (65 kg)
Family band
Conserv. dependent

S. Peru to N.W. Argentina

## CONSERVATION WATCH

**Camelid threats** Of the six species of camelids, two are listed on the IUCN Red List: the Bactrian camel, with about a thousand wild individuals left, is critically endangered, and the vicuña is conservation dependent. The dromedary has been extinct in the wild for many years but is prevalent as a domestic and feral species.

# Pigs

CLASS Mammalia
ORDER Artiodactyla
FAMILY Suidae
GENERA 5
SPECIES 14

Unlike most other ungulates, which are strictly herbivorous, the pigs, hogs, boars, and babirusa in the family Suidae are omnivores with a diet that includes insect larvae, earthworms, and small vertebrates, as well as a wide array of plants. The nostrils on a pig's prominent snout are enclosed in a disk of cartilage. Supported by a unique prenasal bone, this disk helps locate food by shoveling through leaf litter or dirt. The upper and lower canines in both males and females of most species form sharp tusks, which can be used as weapons. Occurring naturally in the forests of Africa and Eurasia, wild pigs have also been introduced in North America, Australia, and New Zealand.

**Status symbols** Thought to display status, the curved tusks of the male babirusa are elongated canine teeth. The upper tusks grow through the skin of the face

**Family ties** Male wild pigs tend either to live alone or to belong to a bachelor band, while females and their offspring live in close-knit family groups that are known as sounders. These young warthogs are following their mother as she grazes

### CONSERVATION WATCH

Feral pigs now threaten native fauna, including other pig species, in many places. Habitat loss has also contributed to the decline of some pigs. Of the 14 species in the family Suidae, 43% are listed on the IUCN Red List, as follows:

- 2 Critically endangered
- 1 Endangered
- 2 Vulnerable
- 1 Data deficient

Warthog
*Phacochoerus africanus*

Padded knees allow for kneeling during feeding

Bush pig
*Potamochoerus larvatus*

Upper tusks can grow to 14 inches (35 cm) long

Giant hog
*Hylochoerus meinertzhageni*

Large folds and wrinkles in skin

Red river hog
*Potamochoerus porcus*

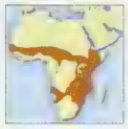
Mane and ear tassels can be fluffed out to increase the animal's apparent size

Lower canines used in fighting

Babirusa
*Babyrousa babyrussa*

## FACT FILE

**Warthog** This grassland grazer kneels on its forelimbs to feed, using its specialized incisor teeth to pluck new growth. When the grasses shrivel during the dry season, it digs out grass rhizomes (underground stems)



Up to 5 ft (1.5 m)
Up to 27½ in (70 cm)
Up to 230 lb (105 kg)
Mainly solitary
Common

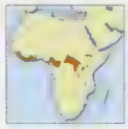
Sub-Saharan Africa

**Bush pig** The adaptable bush pig often follows monkeys to eat the fruit they drop, and will raid crops if they are available. Male rank is determined by head-to-head shoving contests.

Up to 4¼ ft (1.3 m)
Up to 35½ in (90 cm)
Up to 255 lb (115 kg)
Family band
Locally common

E. & S.E. Africa; introd. Madagascar

**Giant hog** Around dusk, a mixed group of giant hogs will retreat through dense vegetation to a large sleeping nest. Females share the care of the piglets, suckling and protecting any in the group. Male contests are fierce, involving collisions at high speed that sometimes produce fractured skulls



Up to 7 ft (2.1 m)
Up to 3¼ ft (1 m)
Up to 520 lb (235 kg)
Family band
Uncommon

C. & W. Africa

**Red river hog** This species digs an underground burrow for sleeping. It rests by day and emerges at night to forage. Red river hogs live in harems of females and young led by a male

Up to 5 ft (1.5 m)
Up to 3¼ ft (1 m)
Up to 285 lb (130 kg)
Family band
Locally common

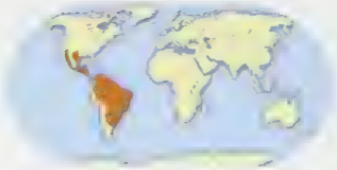
W. Africa

**Babirusa** With a diet of foliage, fruit, and fungi more specialized than that of other pigs, the babirusa also rarely uses its snout to root out food. Fossil studies suggest that it is the most primitive of all pig species.

# PECCARIES

CLASS Mammalia
ORDER Artiodactyla
FAMILY Tayassuidae
GENERA 3
SPECIES 3

Although they resemble the pigs of Suidae in many ways, the three species of peccary in the family Tayassuidae can be distinguished by their long, slender legs, a more complex stomach, and a scent gland on the rump. They are omnivorous like pigs, but prefer fruit, seeds, roots, and vines, with the Chaco peccary depending largely on cacti. These gregarious animals live in herds ranging from 2–10 Chaco peccaries to 50–400 white-lipped peccaries. Social bonds are reinforced by herd members rubbing their cheeks on each other's scent glands. A few white-lipped peccaries will stay behind to fight a predator, allowing the rest of the herd to flee.



**American pigs** While pigs occur naturally only in Africa and Eurasia, peccaries are restricted to the Americas, where they range from southwest United States to northern Argentina. The collared peccary and white-lipped peccary are found in tropical forest, wooded savanna, and thorn scrub. The Chaco peccary is found mainly in semiarid thorn forest

**Twin peccaries** A peccary litter most often contains two young, but can include up to four. Young collared peccaries depend on their mother for about 6 months

**Social species** All peccaries are highly gregarious. Collared peccaries (above) and Chaco peccaries live in herds of several animals. Hundreds of white-lipped peccaries congregate in herds, but split into smaller groups to forage. Like pigs, peccaries are very vocal and use grunts, squeals, and teeth-clattering to communicate

### CONSERVATION WATCH

**Multiple threats** Coupled with hunting for the bushmeat trade and diseases from introduced species, the rapid destruction of South America's tropical forests is having a serious impact on the three species of peccaries, which depend on large home ranges. The Chaco peccary, with only about 5,000 individuals remaining, is listed as endangered on the IUCN Red List.

White-lipped peccary
*Tayassu pecari*

Disk of cartilage at end of snout

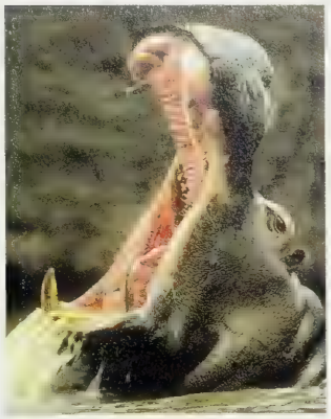
Chaco peccary
*Catagonus wagneri*

Known only from fossils until its discovery in the wild in 1972

# HIPPOPOTAMUSES

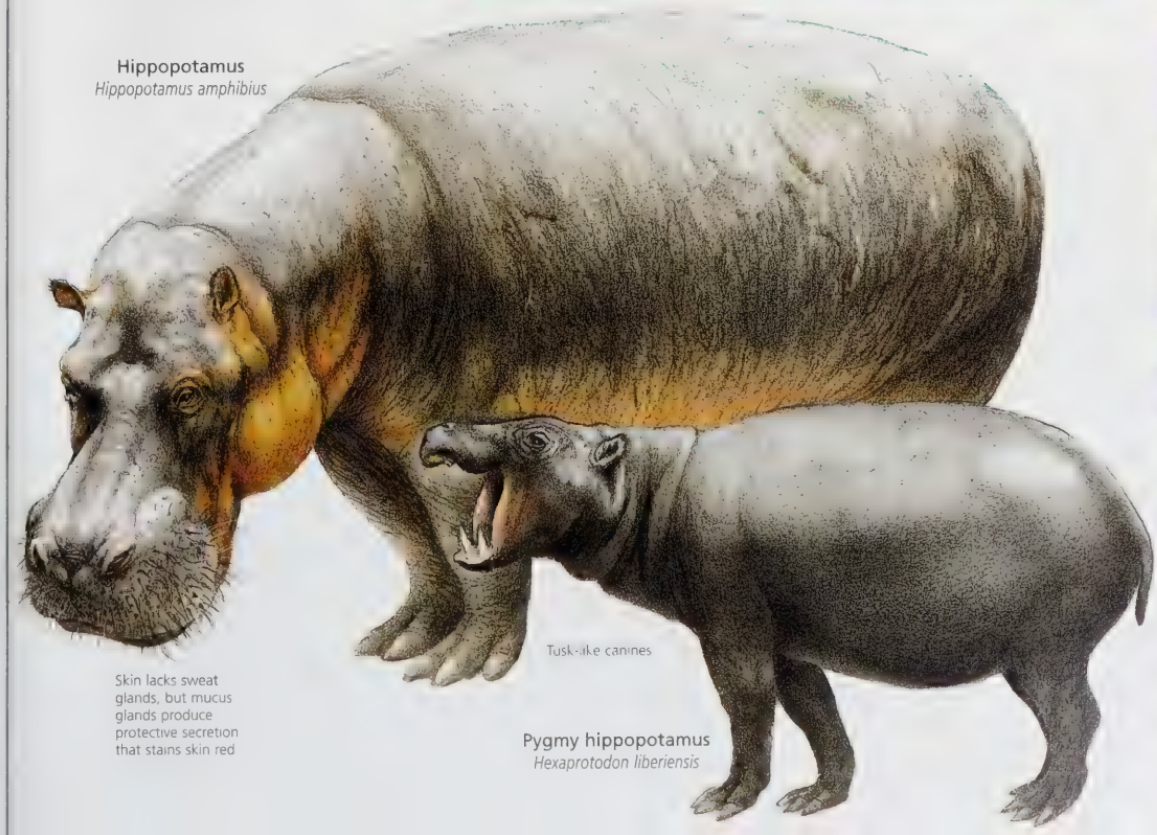
**CLASS** Mammalia
**ORDER** Artiodactyla
**FAMILY** Hippopotamidae
**GENERA** 2
**SPECIES** 4

Now known to be more closely related to whales than to other ungulates, the two surviving species of hippopotamus lead a semiaquatic life, spending the day resting in water and emerging at night to forage on land. Their thick skin has only a thin outer layer, which rapidly dries out and cracks unless regularly moistened. Both species have large heads, a barrel-shaped body, and surprisingly short legs. There is, however, an enormous size disparity, with the grassland-grazing common hippopotamus being seven times heavier than the forest-foraging pygmy hippo. Because their weight is often borne by water, hippos conserve energy and need relatively little food.



**Open wide** Hinged far back in the skull, a hippo's jaw can open remarkably wide, achieving a gape of 150 degrees, more than 100 degrees wider than the human gape. A male's large lower canines are used as weapons in battles for mating rights

**Underwater ungulate** Lacking sweat glands, the common hippopotamus relies on water to stay cool. It is a good swimmer and diver, and the density of its body allows it to walk along a river or lake bed and stay submerged for about 5 minutes at a time. It can float by filling its lungs with air. A hippo's feet are webbed; the nostrils and ears can close underwater; and the eyes, ears, and nostrils are positioned so that it can see, hear, and breathe with just the top of the head emerging above the surface. Young are born and suckled underwater. Herds of up to 40 hippos may spend the day together in water, devoting most of their time to sleeping or resting. At night, they leave the water to feed on land for about 6 hours.




## FACT FILE

**Hippopotamus** Several females and their young spend the day together in water, but forage alone on land at night. Dominant males are territorial and mate with the females that enter their length of riverbank or lake shore. This species mainly eats grasses.

Up to 14 ft (4.2 m)
Up to 5 ft (1.5 m)
Up to 2¼ tons (2 t)
Herd
Locally common

Tropical & subtropical Africa

**Pygmy hippopotamus** Usually solitary, the pygmy hippo may spend the day hidden in a swamp or retreat to an otter's burrow in a riverbank. Its varied diet includes roots and fruit

Up to 6½ ft (2 m)
Up to 35½ in (90 cm)
Up to 605 lb (275 kg)
Solitary, pair
Vulnerable

W. Africa

## CONSERVATION WATCH

**Hippo habitats** While abundant in some areas, the common hippo is rare in western Africa. Its tendency to gather in large herds makes it easy prey for human hunters. Threatened by habitat loss and poaching, the pygmy hippo is listed as vulnerable on the IUCN Red List. Its dense habitat and solitary nature prevent an accurate tally of numbers

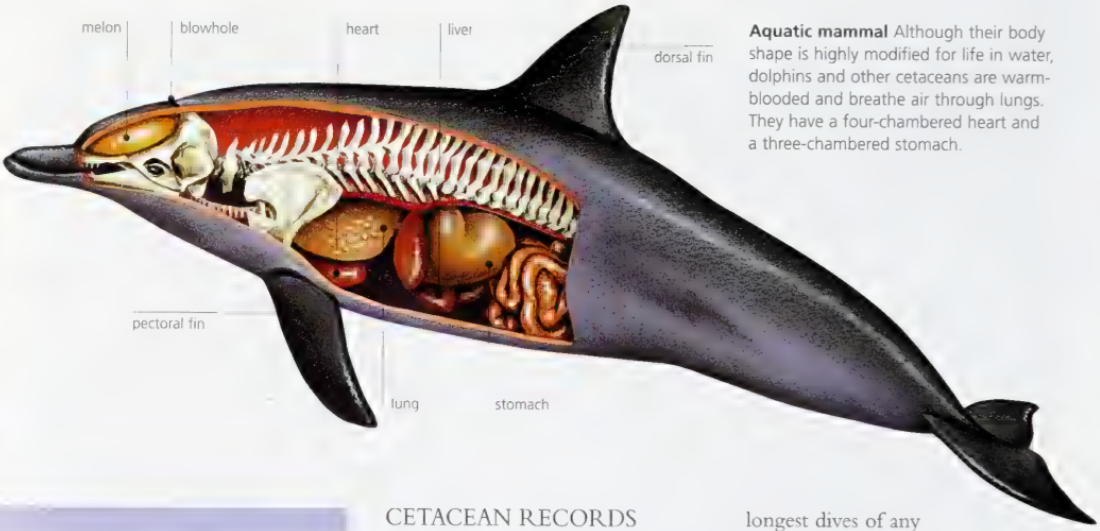
# CETACEANS

CLASS Mammalia
ORDER Cetacea
FAMILIES 10
GENERA 41
SPECIES 81

With their entirely aquatic lifestyle, the whales, dolphins, and porpoises of the order Cetacea are perhaps the most specialized of all mammals. They feed, rest, mate, give birth, and raise young in the water, yet they are warm-blooded and breathe air like other mammals. Gregarious and intelligent, cetaceans appear to be descended from the same land mammal that led to hippopotamuses, but their ancestors adapted to a watery life some 50 million years ago. Over time, they became as streamlined as fish, losing their hair and hindlimbs, modifying their arms into flippers, and developing a powerful fluked tail that makes some species the fastest creatures in the sea.

**Ready to blow** When a cetacean surfaces to breathe, it expels air and condensed moisture through nostrils modified to form a single or double blowhole on the top of the head. The blowhole closes underwater.

**Staying warm and cool** Being virtually hairless, a cetacean relies on a layer of blubber beneath the skin for insulation. A network of arteries and veins in the blubber, known as *retia mirabilia*, helps the animal to regulate its temperature.




**Aquatic mammal** Although their body shape is highly modified for life in water, dolphins and other cetaceans are warm-blooded and breathe air through lungs. They have a four-chambered heart and a three-chambered stomach.

**A double fluke** Like other cetaceans, the sperm whale propels itself with powerful up-and-down strokes of its fluked tail. The flippers are used for steering.

**Bonded young** After a long gestation period, a single calf is born tail-first underwater. Its mother and sometimes other members of the pod nudge it to the surface to take its first breath. Nourished by rich milk, the calf grows rapidly but stays with the mother for some years.

## CETACEAN RECORDS

Cetaceans are found in all of the world's oceans and seas, and in some rivers and lakes. They are split into two living suborders: the toothed whales of Odontoceti, and the baleen whales of Mysticeti. Toothed whales, which include dolphins, porpoises, and sperm whales, have simple, conical teeth that can keep a firm grip on their slippery food of fishes and squids. Baleen whales include blue whales, humpbacks, gray whales, and right whales. They are filter feeders, straining great quantities of tiny plankton, other invertebrates, and small fish through bristled horny plates that hang from the roof of the mouth.

With water supporting their weight, some cetaceans have been able to reach enormous sizes. The blue whale is the largest animal that has ever lived, with a record weight of 209 tons (190 tonnes)—roughly equivalent to the weight of 35 elephants—and a record length of 110 feet (33.5 m).

Another cetacean, the sperm whale, boasts the deepest and longest dives of any mammal. Sperm whales are believed to descend to at least 10,000 feet (3,050 m), and their dives can last for more than 2 hours. When a cetacean dives, its heart rate slows by 50 percent and blood is directed away from the muscles to the vital organs, allowing the animal to survive on very little oxygen until it ascends to breathe.

Cetaceans have little or no sense of smell. Their relatively small eyes provide reasonable vision both above and beneath the water's surface. All species lack external ears, but their hearing is highly sensitive, allowing them to pick up distant calls from members of their species. To find prey and avoid obstacles, toothed whales use echolocation, emitting a series of clicks and whistles, and then analyzing the reflected sounds.

Sound is critical in cetacean communication. Blue whales and fin whales emit low-frequency pulses that carry across vast stretches of ocean and can reach 188 decibels—the loudest sound made by an animal. Male humpbacks produce

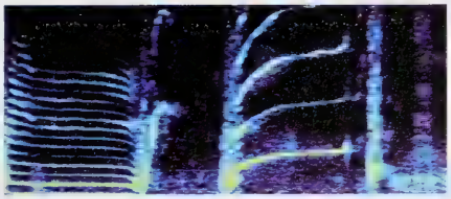
**Clear breach** Humpback whales may leap from the water a hundred or more times in a row. Such breaching appears to be used to communicate with other whales, but may also have other purposes

the longest and most complex songs in the animal kingdom.

Because cetaceans spend most of their time underwater, accurate population statistics are difficult to compile. Nevertheless, it is certain that human activities have devastated cetacean numbers. Commercial whaling (now largely banned, but still pursued by Norway and Japan), driftnet fishing (which inadvertently traps cetaceans), and water pollution have all taken a heavy toll.

**Social animals** Almost all cetaceans are gregarious to some extent. Toothed whales tend to form larger groups than baleen whales and have more complex social structures Hundreds or sometimes thousands of common dolphins travel together, swimming with great speed and leaping clear of the water. Members of a group usually feed at the same time and may hunt cooperatively, herding fish into clusters

**Great migration** Gray whales breed during winter in warm waters near the Equator. Calves rely on their mother's rich milk to build up strength for the long swim to the whales' summer feeding grounds in plankton-rich polar waters Because they do not eat during the 3- to 5-month journey, the adult whales rely on their blubber and fat for energy and may lose up to half their body weight



**Orca song** Each orca pod has a distinct dialect a repetitive pattern of sounds used during travel and feeding that probably helps the animals to coordinate their activities. The calls [illegible]

**Humpback song** [illegible]

# TOOTHED WHALES

CLASS Mammalia
ORDER Cetacea
FAMILIES 6
GENERA 35
SPECIES 68

About 90 percent of all cetaceans are toothed whales belonging to one of the six families in the suborder Odontoceti. In contrast to the enormous baleen whales, toothed whales tend to be medium-sized, although the largest of them, the sperm whale, is a massive creature. Their brains are relatively large, making them the most intelligent mammals other than primates. While some species are solitary, most are highly social and tend to be very vocal and playful. Members of a group may hunt cooperatively and help care for each other's young. Most toothed whales feed on fishes or squids, but one species, the orca, actively pursues warm-blooded prey such as seals and other whales.

**Killer teeth** Toothed whales have sharp, conical teeth. In fish-eating dolphins, these are small and numerous. Orcas, which hunt marine mammals, have fewer but larger teeth (above). Squid-eating beaked whales have just a single tooth per jaw

**Long and narrow** The skeleton of a toothed whale has been greatly modified from that of its land mammal ancestor The hindlimbs have disappeared, while the forelimbs have become flippers, although the bones for five fingers remain. The head is usually long and narrow, forming a beak

**Serious playtime** Dolphins, such as this dusky dolphin (*Lagenorhynchus obscurus*), may leap to impress mates, to herd fish, or simply for fun. Playful displays help to reinforce the social bonds among group members, providing the familiarity needed for successful cooperative hunting

**Gregarious species** Sperm whales live in closeknit groups of about a dozen related females and their young. The adults look after each other's young and will protect an injured member from predators. Young males leave to form bachelor groups, but become less social as they age

### CONSERVATION WATCH

Of the 68 species of toothed whales, 82% are listed on the IUCN Red List, as follows:

| | |
|---|---|
| 2 | Critically endangered |
| 2 | Endangered |
| 4 | Vulnerable |
| 10 | Conservation dependent |
| 38 | Data deficient |

## SOCIAL CETACEANS

The diverse members of Odontoceti include sperm whales; narwhals and belugas; beaked whales; dolphins, orcas, and pilot whales (grouped together in the family Delphinidae); porpoises; and river dolphins. Most have an elongated, beak-like head with sharp, conical teeth that can firmly seize prey but cannot chew it. Because there is only a single blowhole, the skull is asymmetrical. It supports a fluid-filled organ called the melon, which is thought to focus the clicks used in echolocation and communication. In sperm whales, the melon is greatly enlarged and filled with an oil known as spermaceti. This spermaceti organ may also help to focus sounds.

There is considerable variety in the social organization of toothed whales. Most groups are centered on the females, with males leaving the group at puberty. Orcas and pilot whales, however, never leave their birth group. River dolphins tend to form small groups or even live alone. Coastal dolphins form larger groups because their prey is concentrated in particular areas and they face more predators. In the deep ocean, small, closely related groups may form temporary herds containing thousands of dolphins.

Despite their reputation for being gentle and playful, dolphins do fight. Group living often involves rivalry for food or mates, and this may lead to physical clashes. Many toothed whales bear tooth rake marks as scars of such encounters.

Low hump instead of true dorsal fin

**Ganges dolphin**
*Platanista gangetica*

Flexible neck can turn head far to side

Skin dark brown or black at birth, but gradually lightens, becoming white by sexual maturity

Broad tail flukes

**Beluga**
*Delphinapterus leucas*

Skin becomes paler with age

**Narwhal**
*Monodon monoceros*

Tusk covered in algae

Largest of all river dolphins

Good vision in clear water

**Boutu (Amazon dolphin)**
*Inia geoffrensis*

**Franciscana (La Plata dolphin)**
*Pontoporia blainvillei*

Most endangered of all cetaceans

Long, upward-curving snout

**Baiji (white fin dolphin, Yangtze dolphin)**
*Lipotes vexillifer*

## FACT FILE

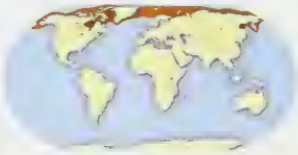
**Ganges dolphin** Almost completely blind, this freshwater dolphin relies on echolocation to navigate its murky habitat, and uses its snout to probe the muddy bottom for shrimps and fishes Like all river dolphins, this species has been severely affected by pollution, damming, and hunting, and only a few thousand individuals survive.

Up to 10 ft (3 m)
Up to 200 lb (90 kg)
Solitary
Endangered

Rivers in India, Bangladesh & Nepal

**Beluga** This gregarious creature has an expressive face and uses a wide range of sounds to communicate. Nicknamed the "sea canary," it emits clicks, claps, moos, chirps, whistles, and clangs.

Up to 16½ ft (5 m)
Up to 3,300 lb (1,500 kg)
Variable
Vulnerable



Arctic Ocean, Gulf of St. Lawrence

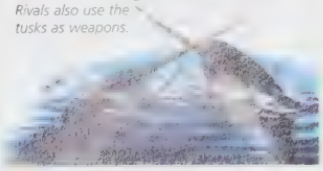
## UNICORNS OF THE SEA

Narwhals have only two teeth, both in the upper jaw. In females, the teeth usually remain embedded, but in males the left tooth erupts and grows into a very long, tightly spiraled tusk, which can reach 10 feet (3 m) in length.

Up to 20 ft (6 m) + tusk 10 ft (3 m)
Up to 3,530 lb (1,600 kg)
Variable
Data deficient

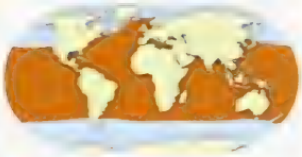
Arctic Ocean

***Jousting tusks*** *The siz[illegible] advertises his strength to [illegible] Rivals also use the [illegible] tusks as weapons.*



## FACT FILE

**Bottle-nosed dolphin** This is the [illegible] known to the [illegible] and to most other [illegible] on the [illegible] and offshore [illegible] of about a [illegible] [illegible] from [illegible] to [illegible], it [illegible] [illegible] swimming at an average speed of 12 [illegible]



**Common dolphin** The most abundant of all dolphins, this [illegible] species [illegible] of [illegible] hundred or even a few thousand individuals. [illegible] may be [illegible] of bottle-nosed dolphins during feeding.

## ENTANGLED VICTIMS

Slender body without dorsal fin or ridge

Northern right-whale dolphin
*Lissodelphis borealis*

Melon-headed whale
*Peponocephala electra*

Male's dorsal fin can measure 6 feet (1.8 m)

Orca
(killer whale)
*Orcinus orca*

May dive to 2,000 feet (600 m) in pursuit of squid

Long-finned
pilot whale
*Globicephala melas*

Males are almost twice as heavy as females

Flexible neck

Irrawaddy dolphin
*Orcaella brevirostris*

Pygmy killer whale
*Feresa attenuata*

Easily confused with overheated false killer whale

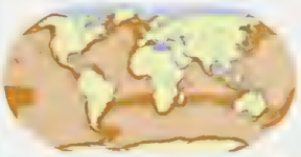
Robust teeth

False killer whale
*Pseudorca crassidens*

## FACT FILE

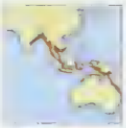
**Orca** This versatile predator will form packs to trap fishes and squids, beach itself to grab sea lions from the shore, or tip over ice floes to send seals and penguins into the sea.

- Up to 32 ft (9.8 m)
- Up to 18 tons (16 t)
- Infame
- Conservation dependent



Normally dwelling in coastal waters

**Irrawaddy dolphin** This species prefers shallow coastal waters, but can live permanently in freshwater rivers. It forms groups of 6–15 animals.

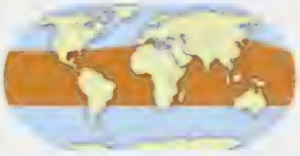


- Up to 9 ft (2.8 m)
- Up to 440 lb (200 kg)
- Family band
- Data deficient

Seas & rivers from Asia to Australia

**Pygmy killer whale** This species mainly feeds on fishes and squids, but has attacked other small cetaceans.

- Up to 9 ft (2.8 m)
- Up to 348 lb (158 kg)
- Herd
- Data deficient



Tropical to subtropical oceans & seas

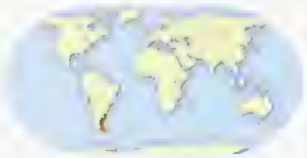
## SEEING WITH SOUND

To find their way around and locate prey, toothed whales emit a series of high-pitched clicks and then listen for the echoes. The clicks are produced in the soft tissues of the head [illegible] to focus the [illegible]

## FACT FILE

**Spectacled porpoise** Less acrobatic than many other small cetaceans, this porpoise moves slowly through the water. It usually lives alone or in pairs and feeds on fishes and squids.

- Up to 7 ft (2.1 m)
- Up to 255 lb (115 kg)
- Solitary, small group
- Data deficient



Off Argentina, Tasmania & sub-Antarctic islands

**Burmeister's porpoise** The species name of this animal (*spinipinnis*) means "spiny fin" and was inspired by the small bumps along the leading edge of its dorsal fin, a characteristic shared by most other porpoises

- Up to 6 ft (1.8 m)
- Up to 154 lb (70 kg)
- Small groups
- Data deficient

Seas & coastal waters from Peru to Brazil

**Gulf porpoise** Found only in the northern part of the Gulf of California, this species has a more restricted range than any other cetacean. It appears to have evolved from South America's Burmeister's porpoise, but was isolated in the Northern Hemisphere when tropical waters became warmer

- Up to 5 ft (1.5 m)
- Up to 121 lb (55 kg)
- Not known
- Critically endangered

Estuary of Colorado River; Gulf of California

**Common porpoise** A rounded shape and small flippers, tail, and fin minimize the cetacean's surface area. Along with a layer of blubber, this helps it survive colder waters despite its small size

- Up to 6¼ ft (1.9 m)
- [illegible]
- [illegible]
- [illegible]

[illegible]

# CETACEAN STRATEGIES

To reap a rich harvest from the ocean, cetaceans have developed remarkably varied physical characteristics and behavioral strategies. Baleen whales have enormous mouths that can engulf huge quantities of tiny animals, while toothed whales pursue individual prey, relying on echolocation to find it. Many species practise cooperative hunting, using a range of vocalizations to communicate the next move. The success of such efforts rests on a social structure that encourages close relationships.

**Humpback feeding** Humpbacks (above) will synchronize their feeding, lunging at prey shoals together or herding scattered prey into clusters. In bubblenet feeding (below), a humpback spirals toward the surface while exhaling, producing a large "net" of bubbles that traps small prey. The whale lunges through the center of the net to capture its meal.

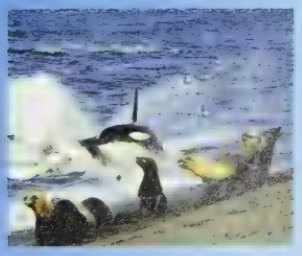
***1. Slow exhale*** *As a humpback whale spirals to the surface, it slowly lets out its breath, creating columns of bubbles. Small schooling fishes are trapped inside the net of bubbles.*

***2. Group effort*** *Bubblenetting may be carried out by a single whale, or several whales may cooperate to create the net*

***3. Lunge feeding*** *Once the bubblenet has trapped the fishes, the humpback swims through the center, lunging to the surface with its mouth open to engulf the prey.*

**Clicking pursuit** Toothed whales track their food using echolocation. A dolphin may emit up to 600 clicks a second, analyzing the echoes to build up a picture of its surroundings, including the position of prey. Orcas use echolocation when pursuing fish, but rely more on vision to hunt other cetaceans or seals, which would be alerted by the clicks.

**Bottom feeder** A gray whale feeds in shallow waters on bottom-dwelling crustaceans, mollusks, and worms. It dives to the seafloor, turns on its side, and then sucks up a mouthful of sediment. Prey is filtered out by pushing the sediment through its baleen.

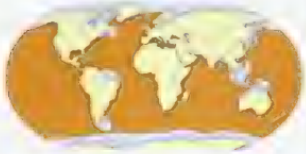


**Together and alone** [illegible] on the prey [illegible] locally [illegible] hunting [illegible]

## FACT FILE

**Sperm whale** With a gullet large [illegible] to swallow a human, the [illegible] sperm whale sometimes [illegible] sharks and skates, but mainly [illegible] giant squids, octopuses, and [illegible] fishes. It is gregarious and [illegible] in groups of 30–100 animals

- Up to [illegible] 18.5 m
- Up to 77 tons (70 t)
- Variable
- Vulnerable



[illegible] temperate to tropical oceans & seas

**Baird's beaked whale** Tightly knit social groups of 6–30 Baird's beaked whales live in deep offshore waters and are led by a dominant male. Rivalry for this position often leads to physical conflict, with most males bearing scars on their beak and back

- [illegible]
- [illegible]
- [illegible]
- [illegible] dependent

[illegible]

### TUSKED BEAKS

A diet of squids captured through suction has rendered beaked whales [illegible] toothless. In males, however, one or two pairs of teeth protrude from the mouth to form tusks, which [illegible] used as weapons

[illegible]

# BALEEN WHALES

**CLASS** Mammalia
**ORDER** Cetacea
**FAMILIES** 4
**GENERA** 6
**SPECIES** 13

The giants of the ocean, the baleen whales of the suborder Mysticeti feed on tiny prey, filtering aquatic invertebrates and small fishes through their sieve-like baleen plates. Their remarkable size is a great advantage in cooler waters, since, relative to body mass, they have a small surface area from which to lose heat. A thick layer of blubber provides insulation and can act as a food store for the epic annual migrations that many species undertake. Found in all the world's oceans, baleen whales include the gray whale, the right whales, the bowhead whale, and the rorquals—which comprise the blue whale, fin whale, sei whale, Bryde's whale, humpback whale, and minke whales.

**Legal whaling** For nutritional and cultural reasons, the Inuit (above) are permitted to hunt a small number of bowhead whales each year. The eastern bowhead population went into a severe decline as a result of the commercial whaling of the 19th century, but appears to be slowly stabilizing

**Great gulp** Like other rorquals, humpback whales have a pleated throat that expands into a great pouch as they gulp in water and plankton. The throat contracts again as they force the water back out and trap the prey in their bristled baleen plates.

**Distinguishing marks** Right whales are distinguished by the callosities on their head, patches of hardened skin that are often infested with parasites such as lice and barnacles. The callosities are slightly larger on male whales than on females, suggesting that they may be used as weapons by rivals.

**Light bones** Rather than supporting the animal's body weight, a cetacean's skeleton simply anchors the muscles. The bones are light, spongy, and filled with oil. The most dramatic feature of a baleen whale's skeleton is the massive head

## BALEEN AND BLUBBER

Baleen whales can be skimmers or gulpers. Right whales move slowly along the surface, skimming little animals from the water that crosses their long baleen plates. Rorquals lunge at shoals of prey with open mouths, gulp in water, and then force the water back out with their tongues, trapping krill and other creatures in their short plates. Gray whales are bottom feeders, filtering crustaceans and mollusks from the sediment with their heavy baleen.

Most of a baleen whale's prey species are minuscule, so it needs to consume vast quantities to stay alive. During summer, a large blue whale may eat 4½ tons (4 tonnes) of krill per day. It feeds very little during the rest of the year and lives off the fat and blubber laid down in summer.

Baleen and blubber, both crucial to the survival of these giants, also attracted commercial whalers. Since 1985, there has been a moratorium on all commercial whaling, but this is not observed by Norway or Japan.

### CONSERVATION WATCH

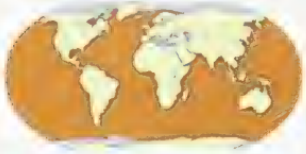
All 13 species of baleen whales are listed on the IUCN Red List, as follows

- 5 Endangered
- 1 Vulnerable
- 4 Conservation dependent
- 1 Data deficient

## FACT FILE

**Blue whale** Consuming about 4½ tons (4 tonnes) of krill every day during the main summer feeding season, the blue whale is the largest animal to have ever lived. A newborn measures at least 19½ feet (5.9 m) and guzzles 50 gallons (190 l) of milk per day, adding 8 pounds (3.6 kg) to its weight every hour. It may go on to live for 110 years. Blue whales were relentlessly hunted in the early to mid 20th century, and the total population now comprises only 6,300–14,000 individuals

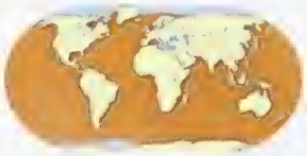
- Up to 110 ft (33.5 m)
- Up to 200 tons (180 t)
- Variable
- Endangered



All oceans except high Arctic

**Fin whale** Outsized only by the blue whale, the fin whale can attain speeds of 23 miles per hour (37 km/h), making it one of the fastest cetaceans. While groups of 300 or more may migrate together, the species is usually seen in pairs or small pods of several animals

- Up to 82 ft (25 m)
- Up to 88 tons (80 t)
- Variable
- Endangered

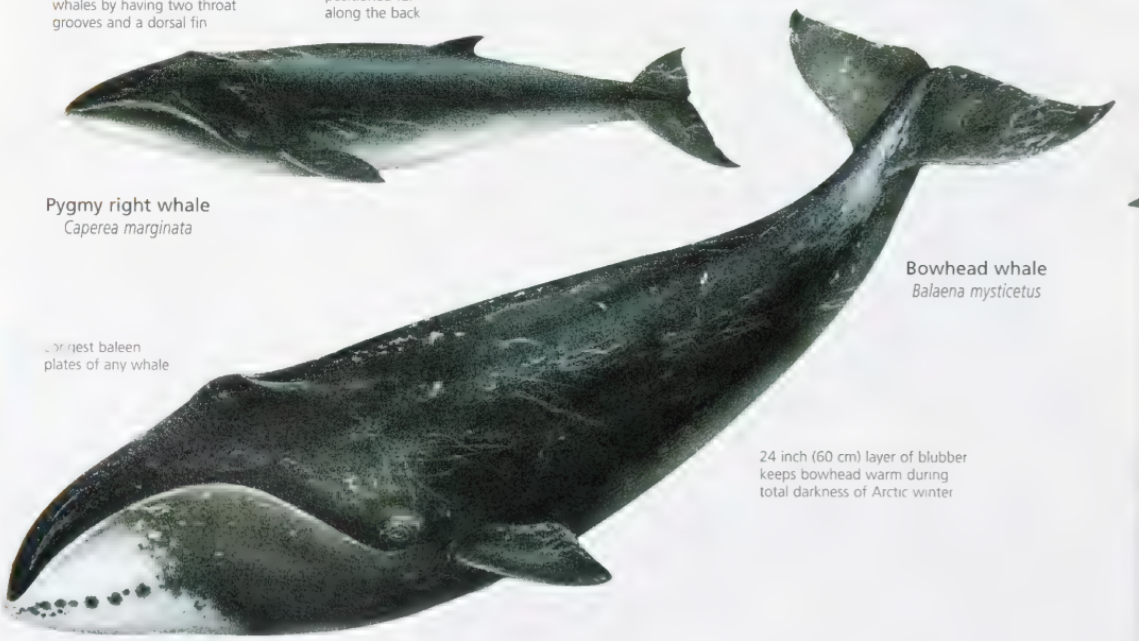


[illegible] except high Arctic

**Northern right whale** Full of oil and [illegible] species was named the "right" whale for hunting by early [illegible] whalers. There are now only [illegible]

- [illegible]
- [illegible]
- [illegible]
- [illegible]

[illegible]



99 percent of blue whales were killed by 20th-century whalers

Female larger than male

Fin whale's lower jaw has asymmetrical color pattern white on the right side and dark on the left

Minke whale
*Balaenoptera acutorostrata*

Sei whale's short throat pleats and fine baleen fringes for skimming food from water as whale swims on its side

Sei whale
*Balaenoptera borealis*

Mature gray whales are covered in lice and barnacles

Gray whale
*Eschrichtius robustus*

Reduced dorsal fin forms small hump on back

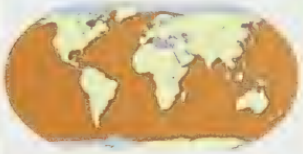
Humpback whale
*Megaptera novaeangliae*

97 percent of humpbacks were killed by 20th-century whalers

## FACT FILE

**Minke whale** The smallest and most abundant rorqual, this acrobatic whale is found in all the world's oceans. It is often seen in pairs, but up to 100 may gather in a rich feeding area.

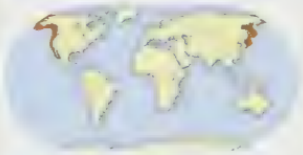
- Up to 36 ft (11 m)
- Up to 11 tons (10 t)
- Variable
- Near threatened



Most ocean areas except coldest regions

**Gray whale** Many gray whales make a 12,400 mile (20,000 km) round-trip from summer feeding grounds in Alaska to winter breeding grounds in Mexico.

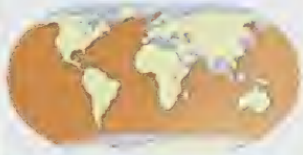
- Up to 49 ft (15 m)
- Up to 38½ tons (35 t)
- Variable
- Conservation dependent



Bering Sea to Gulf of Mexico & Sea of Okhotsk

**Humpback whale** This active animal is famous for spectacular breaching, when it leaps clear of the water. Other surface behaviors include rolling, pec-slapping, spyhopping (sticking its head vertically out of the water), and tail splashing.

- Up to 49 ft (15 m)
- Up to 71½ tons (65 t)
- Variable
- Vulnerable



Breeds in tropics, feeds near Arctic

# RODENTS

CLASS Mammalia
ORDER Rodentia
FAMILIES 29
GENERA 442
SPECIES 2,010

With roughly 2,000 species, rodents account for more than 40 percent of all mammal species and have colonized almost every habitat on Earth. A key to their extraordinary success is the ability to reproduce quickly and abundantly, allowing species to survive harsh conditions and take full advantage of favorable ones. In addition, the small size of most rodents has helped them to exploit many microhabitats. Although rodents are among the earliest of placental mammals, with the oldest rodent fossils dating back some 57 million years, the largest family, Muridae (rats and mice), did not appear until 5 million years ago. It now contains almost two-thirds of all species in the order.

**Successful spread** Members of the order Rodentia are distributed throughout all the world's continents, except for Antarctica. Their association with humans has even helped them to reach isolated islands. They have adapted to a wide range of habitats, including arctic tundra, tropical forests, deserts, high mountains, and urban areas.

**Persistent pests** Being opportunistic feeders that can reproduce quickly, many rodents have thrived alongside humans. Pests such as black rats (left) not only eat vast quantities of crops and stored food, but also contaminate the remaining food with their droppings and spread disease.

**Rapid reproduction** Garden dormice usually mate in April or May after waking from their winter hibernation. Following a short gestation period of 22–28 days, the female gives birth to 2–9 young. The newborn are entirely dependent on the mother and will not open their eyes for another 21 days or so. They become independent by 6 weeks and then grow rapidly until their first hibernation. While some rodent species are ready to breed at 6 weeks, it takes about a year for garden dormice to become sexually mature. A captive garden dormouse lived for about 5½ years, a long lifespan for a rodent.

**Typical rodent** The brown rat displays the typical rodent anatomy, with a compact body, short legs, clawed feet, long tail, and sensitive whiskers. A keen sense of smell and sharp hearing help rodents to find food and avoid predators.

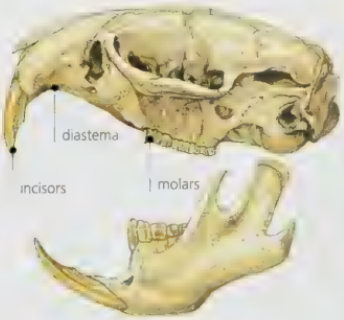
## UNIFORM ANATOMY

Rodent size ranges from the tiny pygmy jerboa, less than 2 inches (5 cm) long and weighing just ⅙ ounce (5 g), to the substantial capybara, more than 50 inches (1.3 m) in length with a weight of 140 pounds (64 kg). Typically, however, rodents are small with squat bodies, short legs, and a tail.

The most distinguishing rodent feature is the arrangement of the teeth. All rodents have two pairs of extremely sharp incisors at the front of the mouth that can gnaw through seedpods, nut shells, and other tough matter to get at the nutritious food inside. The incisors grow continuously and are "self-sharpened" against each other. There are no canine teeth behind the incisors. Instead, a gap known as the diastema allows the lips to close during gnawing so inedible material is kept out of the mouth. At the back of the mouth, a series of molars grind up the plant matter that makes up most of a rodent's diet.

While a few rodents are mainly carnivorous, most are opportunistic feeders and eat leaves, fruit, nuts, and seeds, as well as caterpillars, spiders, and other small invertebrates. The indigestible cellulose in plant walls is broken down by bacteria in

**Flexible feeder** A resident of temperate forests, the red squirrel eats mainly seeds and nuts, but will also consume flowers, shoots, fungi, and small invertebrates. It builds up a cache of buried seeds and nuts that it can raid during the cold winter




**Gnawing teeth** A gap called the diastema separates a rodent's chewing molars from the sharp, continuously growing incisors. The diastema allows the lips to close behind the incisors and keep out inedible material when the animal is gnawing

**Ecosystem role** As key prey species for medium-sized predators such as this barn owl, rodents play an important role in an ecosystem. Their distribution of the spores of fungi that nourish tree roots is also vital in North American and Australian forests.

**A rodent's tail** The diversity of rodent lifestyles is reflected in the various shapes and purposes of the tail (right). The northern flying squirrel (*Glaucomys sabrinus*) (above) uses its tail for steering and stability as it glides from tree to tree

the large cecum (appendix) of the rodent digestive system. Some species then take this treated food from the anus and eat it again, gaining maximum nutrition from the meal before passing feces as dry pellets, a process known as refection.

Intelligent and resourceful, rodents have put their relatively uniform anatomy to diverse use. Many species are terrestrial, finding their food in forests, grasslands, deserts, or human settlements. Others spend most of their time in trees, scampering over branches and, in some cases, gliding from one tree to another. Some species make their life underground in extensive networks of burrows. And a few are excellent swimmers, able to pursue a semiaquatic lifestyle. While a minority of rodents are solitary, most are highly social, a trait culminating in the townships that contain thousands of prairie dogs.

The order Rodentia was once split into three suborders according to the arrangement of jaw muscles: squirrel-like rodents, mouse-like rodents, and cavy-like rodents. These categories are still used informally for ease, but genetic evidence points to a division into just two suborders. The suborder Sciurognathi includes all the squirrel-like and mouse-like rodents, plus the gundis, a family of cavy-like rodents. The other suborder, Hystricognathi, includes all other cavy-like rodents.

## CONSERVATION WATCH

Some rodent species have thrived alongside humans to the point of becoming serious pests. Many with limited ranges, however, have been threatened or even driven extinct by human activities. Of the 2,010 species of rodents, 33% are listed on the IUCN Red List, as follows:

| | |
|---|---|
| 32 | Extinct |
| 68 | Critically endangered |
| 95 | Endangered |
| 165 | Vulnerable |
| 5 | Conservation dependent |
| 255 | Near threatened |
| 49 | Data deficient |

# SQUIRREL-LIKE RODENTS

CLASS Mammalia
ORDER Rodentia
FAMILIES 8
GENERA 71
SPECIES 383

The squirrels, beavers, and other animals collectively known as squirrel-like rodents share an arrangement of jaw muscles that gives them a strong forward bite. They have simple teeth and have retained one or two premolar teeth in each row, a characteristic not found in other rodents. Aside from the jaw muscles and premolar teeth, the families of squirrel-like rodents share few characteristics and probably diverged from each other early in rodent evolution. They include beavers (family Castoridae), mountain beaver (Aplodontidae), squirrels (Sciuridae), pocket gophers (Geomyidae), pocket mice (Heteromyidae), scaly-tailed squirrels (Anomaluridae), and springhare (Pedetidae).

**Winter sleep** From October until March or April, the woodchuck (*Marmota monax*) hibernates underground in burrows. During this time, its heartbeat slows, its body temperature falls, and it lives off body fat It mates soon after emerging in spring

**Arboreal leaper** When a tree squirrel such as this American red squirrel leaps from one tree to another, it stretches out its limbs, flattens its body, and slightly curves its tail to maximize its surface area. The long, bushy tail acts as a rudder

**Social species** Prairie dogs live in large townships with a complex social structure A township is made up of many coteries—groups of one male, several related females, and their offspring. Members of a coterie share burrows and food

**Strong forward bite** The

### CONSERVATION WATCH

Of the 383 species of squirrel-like rodents, 21% are listed on the IUCN Red List, as follows:

- 8 Critically endangered
- 11 Endangered
- 3 Conservation dependent
- 58 Near threatened
- 2 Data deficient

## BURROWERS AND LEAPERS

The squirrels in the family Sciuridae make up about three-quarters of all squirrel-like rodents. Active by day, tree squirrels have long, lightweight bodies, sharp claws for clinging to bark, and excellent eyesight for judging distances. They move about by scampering along branches, climbing headfirst down trunks, or leaping from tree to tree. The nocturnal flying squirrels glide through the air, aided by a furred membrane along either side of the body. Arboreal squirrels mostly feed on fruit, nuts, seeds, shoots, and leaves, but may supplement this diet with insects. Ground-dwelling squirrels, which include ground squirrels, prairie dogs, marmots, and chipmunks, tend to favor grasses and herbs. Many of these terrestrial species are gregarious with complex social organization.

Scaly-tailed squirrels are only distantly related to true squirrels. Like tree squirrels, almost all species of scaly-tailed squirrels possess a membrane for gliding—an example of convergent evolution.

Beavers are superbly equipped for a life spent largely in water, with a streamlined body, flattened tail, and webbed feet. Their large incisor teeth allow them to cut down trees and build dams and lodges.

Pocket gophers, pocket mice, mountain beavers, and springhares are all burrowing rodents. The pocket gophers and pocket mice both carry food in cheek pouches on either side of the mouth.

Cheek pouches inside mouth for carrying food

**Spotted souslik**
*Spermophilus suslicus*

**European souslik**
*Spermophilus citellus*

Stands on hindlegs to watch for predators

Whistles to warn other marmots of danger

**Bobak marmot**
*Marmota bobak*

**Alpine marmot**
*Marmota marmota*

**Hoary marmot**
*Marmota caligata*

Sturdy, slightly curved claws for digging

**Thirteen-lined ground squirrel**
*Spermophilus tridecemlineatus*

13 stripes alternating between light and dark fur

**Black-tailed prairie dog**
*Cynomys ludovicianus*

Poor eyesight but keen hearing and sense of touch

**Mountain beaver**
*Aplodontia rufa*

## FACT FILE

**Thirteen-lined ground squirrel** Active by day, this rodent feeds mainly on grasses and seeds, transporting some food in its cheek pouches to underground caches

- Up to 7 in (18 cm)
- Up to 5 in (13 cm)
- Up to 9½ oz (270 g)
- Solitary
- Locally common

Tallgrass prairies of C. North America

**Black-tailed prairie dog** Members of this gregarious species play together, groom one another, and communicate with a range of calls. An alarm bark warns of danger, while another type of bark gives the "all clear" signal.

- Up to 13½ in (34 cm)
- Up to 3½ in (9 cm)
- Up to 3½ lb (1.5 kg)
- Family band, colonial
- Near threatened

Shortgrass prairies of W. North America

**Mountain beaver** Strictly terrestrial, the mountain beaver lives in a network of underground tunnels and chambers. It is mostly solitary but spends limited time with other members of its species

- Up to 16½ in (42 cm)
- Up to 2 in (5 cm)
- Up to 2½ lb (1.2 kg)
- Solitary
- Near threatened

S.W. Canada to N. California

## MARMOTS

Restricted to the Northern Hemisphere, marmots are found mainly in mountain habitats. They are true hibernators, and spend the harsh winter at rest in their burrows, living off body fat. All marmots, except for the woodchuck, live in family groups. Young female marmots often stay with their parents to help raise their siblings.

***Face to face*** *Like almost al*
*Olympic marmots (M*
*highly social. Young*

## FACT FILE

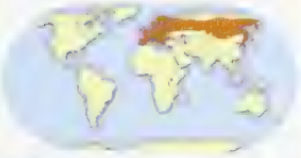
**Eastern gray squirrel** In addition to maintaining a den in a hollow log, this squirrel builds a nest of twigs and leaves lined with grasses and shredded bark in the branches of a tree. The nest is used for resting and feeding, and may also serve as a nursery

- Up to 11 in (28 cm)
- Up to 9½ in (24 cm)
- Up to 26½ oz (750 g)
- Solitary
- Common

S. Canada to Texas & Florida

**Eurasian red squirrel** Using its strong incisors, this squirrel can crack a tough nut in a few seconds. It spends much of the day collecting seeds and nuts, as well as fungi, birds' eggs, and tree sap

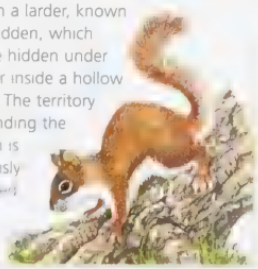
- Up to 11 in (28 cm)
- Up to 9½ in (24 cm)
- Up to 10 oz (280 g)
- Solitary
- Near threatened



Europe to E. Russia, Korea & N. Japan

### SQUIRREL LARDER

Like many tree squirrels in climates with harsh winters, the American red squirrel prepares for the cold months by storing food. It collects thousands of pine and spruce cones and caches them in a larder, known as a midden, which may be hidden under a log or inside a hollow stump. The territory surrounding the midden is vigorously defended



## CONSERVATION WATCH

**Competing squirrels** While the Eurasian red squirrel has remained common in much of central Europe, overhunting has led to a fall in numbers in eastern Europe. The species has now vanished from most parts of Great Britain, outcompeted for resources by the eastern gray squirrel, which was introduced from North America in 1902

Prevost's squirrel
*Callosciurus prevostii*

Nests high in forest canopy but feeds at lower levels

Horse-tailed squirrel
*Sundasciurus hippurus*

Southern flying squirrel
*Glaucomys volans*

Siberian flying squirrel
*Pteromys volans*

Gliding membrane, or patagium, is folded when squirrel is sitting

Red bush squirrel
*Paraxerus palliatus*

Handles food with dextrous forepaws

Soil often tints coat

Striped ground squirrel
*Xerus erythropus*

Gambian sun squirrel
*Heliosciurus gambianus*

Sits up on hindlegs to eat or look for danger

Eastern chipmunk
*Tamias striatus*

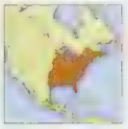
Smallest squirrel in the world

Five black stripes on back

African pygmy squirrel
*Myosciurus pumilio*

## FACT FILE

**Southern flying squirrel** While this nocturnal glider eats mainly nuts and acorns, it also consumes many insects and young birds. It often lives in pairs, but larger groups may den together during the winter months.



Up to 5½ in (14 cm)
Up to 4½ in (12 cm)
Up to 3 oz (85 g)
Pair, small group
Locally common

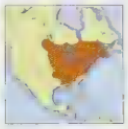
S. Canada to E. USA

**Striped ground squirrel** Like prairie dogs, this gregarious animal lives in colonies and is highly vocal, warning of danger with an alarm call.

Up to 16 in (40 cm)
Up to 12 in (30 cm)
Up to 2 lb (1 kg)
Colonial
Locally common

W. Africa to Kenya

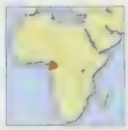
**Eastern chipmunk** This usually solitary species shelters in a burrow. When its cheek pouches are stuffed with food, they can be as large as its head.



Up to 6½ in (17 cm)
Up to 4½ in (12 cm)
Up to 5½ oz (150 g)
Solitary
Locally common

S.E. North America

**African pygmy squirrel** About the size of a man's thumb, this species is the smallest of all squirrels. It lives in the hollow trunks of trees

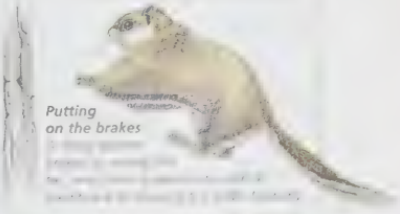


Up to 3 in (7.5 cm)
Up to 2½ in (6 cm)
Up to ½ oz (17 g)
Solitary
Vulnerable

Equatorial Africa

## GLIDING

A flying squirrel can glide for more than 330 feet (100 m), using much less energy than climbing would require and allowing it to escape flightless predators. In most species, the gliding membrane that extends from wrist to ankle is tucked away when climbing



*Putting on the brakes*

# LUMBERJACK RODENTS

The great engineers of the animal world, beavers deliberately alter their environment by building dams, canals, and lodges. While often causing conflict with farmers and other humans, this construction work has an important ecological function, helping to reduce erosion and flooding and creating new habitats for aquatic species. Beavers live in family groups of a monogamous pair and several offspring. They communicate using various calls and postures and will slap their tails against the water to warn of danger. Although similar in appearance and behavior, the two species of beaver—the North American *Castor canadensis* and the Eurasian *C. fiber*—do not interbreed.

**Chopping chisels** Like all rodents, beavers have self-sharpening incisor teeth that never stop growing. The outer surface is protected by tough enamel, but the inner surface is softer and wears away as the beaver gnaws, creating a sharp, chiseled edge.

**Winter quiet** Beavers usually feed and build at night. Through snowy winters, however, they rarely emerge from their lodge, which provides a warm environment. For food, they rely on sticks and logs stored underwater, as well as the fat stored in the tail

**Lodges and dams** A beaver colony may share a riverbank burrow system or they may build a lodge in the water A lodge is a dome of sticks and mud with underwater entrances leading to a vegetation-lined living area above the water level. To create a calm pond for their lodge, beavers will construct dam walls that stop the flow of water They will also dig out canals to link their dam to nearby sources of food and construction material. Several generations of beavers may maintain a dam, but eventually the pond silts up and the resident family must find a new location for their home

**Aquatic adaptations** A beaver uses its flat, scaly tail and webbed rear feet to propel its streamlined body through the water. Clear eyelids shield the eyes underwater, while valved nostrils and ears keep out water. Thick, oil-coated fur insulates the animal in cold water.

***Beaver babies*** *Beaver litters contain an average of two to four kits, which are nursed for 6–8 weeks The kits grow quickly, but will stay with their family group for up to 2 years so they can learn the craft of building dams and lodges.*

***Stopping the flow*** *Beavers use mud, stones, sticks, and branches to construct a dam wall. The pond this creates acts as a moat around their lodge and deters most predators.*

***Rapid recovery*** *Beavers prefer aspens, poplars, alders, and willows. These are all trees that grow rapidly and may even be reinvigorated after being felled by a beaver.*

Lord Derby's anomalure
*Anomalurus derbianus*

Flightless scaly-tailed squirrel
*Zenkerella insignis*

Only scaly-tailed squirrel that does not glide

Pel's anomalure
*Anomalurus pelii*

Can glide more than 330 feet (100 m) between trees by spreading gliding membrane

Speke's pectinator
*Pectinator spekei*

Springhare
*Pedetes capensis*

Long, bushy tail provides balance when hopping

Gundi
*Ctenodactylus gundi*

Toes of hindfeet bear comb-like bristles

Large incisors used to chop down trees

Eurasian beaver
*Castor fiber*

Flattened, scaly tail used for propulsion and steering when swimming

Webbed toes

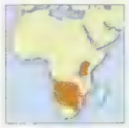
## FACT FILE

**Gundi** Once classified as a cavy-like rodent, but now grouped with squirrel-like and mouse-like rodents in the suborder Sciurognathi, the gundi eats a variety of desert plants and never drinks, extracting water from its food instead

Up to 8 in (20 cm)
Up to 1 in (2.5 cm)
Up to 10 oz (290 g)
Family group, colonial
Locally common

N. Africa

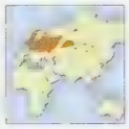
**Springhare** Like a little kangaroo, the springhare has long hindlimbs that it uses for hopping. After sheltering from the heat of the day in its burrow, this rodent emerges at night to forage on grasses and crops.



Up to 17 in (43 cm)
Up to 18½ in (47 cm)
Up to 9 lb (4 kg)
Solitary
Vulnerable

E. & S. Africa

**Eurasian beaver** This semiaquatic rodent is strictly herbivorous, feeding mainly on water plants. It will also eat aspen trees, while it chops down alder and oak trees as building material.



Up to 31½ in (80 cm)
Up to 17½ in (45 cm)
Up to 55 lb (25 kg)
Pair, family band
Near threatened

W. Europe to E. Siberia

## SCALY TAILS

The scaly-tailed squirrels of the Anomaluridae family are not directly related to the true squirrels of Sciuridae. All but one species moves about by gliding, an adaptation that developed independently in flying squirrels. The scales near the base of the tail help scaly-tailed squirrels cling to trees at the end of a glide and then climb back up the trunk.

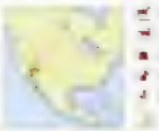
## CONSERVATION WATCH

**Hollow sites** Most of tropical Africa's scaly-tailed squirrels are considered near threatened. They depend on hollow trees for their nesting sites, but such trees are found only in old-growth forests, which are rapidly being cleared for agriculture.

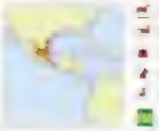
## FACT FILE

**Heteromyidae** [illegible]

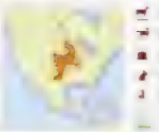
**Long-tailed pocket mouse** [illegible]



**Mexican spiny pocket mouse** [illegible]

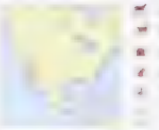


**Plains pocket gopher** [illegible]



**Big-eared kangaroo rat** [illegible]

**Desert kangaroo rat** [illegible]



# MOUSE-LIKE RODENTS

| | |
|---|---|
| CLASS | Mammalia |
| ORDER | Rodentia |
| FAMILIES | 3 |
| GENERA | 306 |
| SPECIES | 1,409 |

More than a quarter of all mammal species are mouse-like rodents. Once grouped within their own suborder, these rodents share an arrangement of the chewing muscles that provides a versatile gnawing action. They also all have a maximum of three cheekteeth in each row. While their lifespan tend to be short, most are early and prolific breeders. The group is dominated by the Muridae family, which has more than 1,000 species, including Old World and New World rats and mice; voles and lemmings; hamsters; and gerbils. The other families of mouse-like rodents are the dormice of Myoxidae and the jumping mice, birchmice, and jerboas of Dipodidae.

**On the scent** [illegible]

**Fruit feeder** Dormice (above) and most other mouse-like rodents are mainly herbivorous, feeding on a diet of seeds, fruit, and buds supplemented by the occasional insect. Voles and lemmings have specialized to feed on grasses. A few species are more carnivorous. Water rats will sometimes add a frog or fish to their diet of aquatic invertebrates, while brown rats may even attack poultry or rabbits.

**Big families** Rats and mice are prolific breeders. Most mature quickly, have short gestation periods, and produce many large litters. In some species, a single pair and their offspring can produce thousands of animals in less than a year.

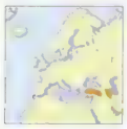
**Versatile action** The arrangement of their jaw muscles provides mouse-like rodents with a versatile gnawing action. The deep masseter extends onto the upper jaw and works together with the lateral masseter to pull the jaw forward for chewing.

## RAPID RADIATION

[illegible]

## FACT FILE

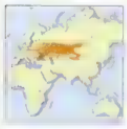
**Golden hamster** Now a popular pet and the best known of the hamsters, this species is endangered in the wild. It was introduced to the United States and England in the 1930s and has since proliferated in captivity.



Up to 7 in (18 cm)
Up to ⅞ in (2 cm)
Up to 5½ oz (150 g)
Solitary
Endangered

Middle East, S.E. Europe, S.W. Asia

**European hamster** This solitary burrower hibernates through winter, waking once a week or so to feed on its massive hoard of seeds and roots. During warmer months, it stocks up this winter food supply, carrying plant matter in its cheek pouches.



Up to 12½ in (32 cm)
Up to 2½ in (6 cm)
Up to 13½ oz (385 g)
Solitary
Common

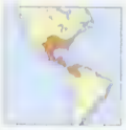
Belgium to Altai Mts of C. Asia

**Eastern woodrat** Nocturnal and solitary, this species falls prey to owls, weasels, and snakes. It protects its nest by building a shelter of sticks, bones, and leaves in a rock crevice or between tree roots.

Up to 10½ in (27 cm)
Up to 7 in (18 cm)
Up to 9 oz (260 g)
Solitary
Common

S.E. USA

**Hispid cotton rat** After a gestation of just 27 days, females of this species give birth to several fully furred young. The female is ready to mate again almost immediately, while the young are sexually mature within 40 days.



Up to 8 in (20 cm)
Up to 6½ in (16 cm)
Up to 8 oz (225 g)
Solitary
Common

S.E. USA to N. Venezuela & N. Peru

**Deer mouse** This small omnivore has adapted to diverse habitats, from boreal forest to desert. It breeds very quickly, with females producing up to four litters of 4–9 young each year.

Up to 4 in (10 cm)
Up to 4½ in (12 cm)
Up to 1 oz (30 g)
Solitary
Common

Long-clawed mole-vole
*Prometheomys schaposchnikowi*

Long claws for digging burrows

European water vole
*Arvicola terrestris*

Siberian collared lemming (Arctic lemming)
*Dicrostonyx torquatus*

White winter coat

Lives farther north than any other rodent

Brown summer coat

Bank vole
*Clethrionomys glareolus*

Great gerbil
*Rhombomys opimus*

Wood lemming
*Myopus schisticolor*

Norway lemming
*Lemmus lemmus*

Tail flattened vertically for use as rudder

Small webs between toes

Muskrat
*Ondatra zibethicus*

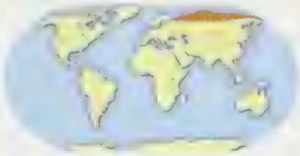
Largest of the voles

Libyan jird
*Meriones lybicus*

## FACT FILE

**Siberian collared lemming** This tundra species spends summer in shallow burrows in high, rocky areas. In winter, it moves to lower meadows and shelters in tunnels under the snow

- Up to 6 in (15 cm)
- Up to ½ in (1 cm)
- Up to 3 oz (90 g)
- Solitary
- Common



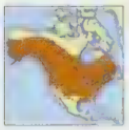
Arctic Eurasia

**Great gerbil** To survive cold winters, large groups of these gerbils huddle together in extensive burrows, not only providing each other with warmth but also protecting their stockpile of plants.

- Up to 8 in (20 cm)
- Up to 6½ in (16 cm)
- Not known
- Colonial
- Common

Caspian Sea to Mongolia, China & Pakistan

**Muskrat** This semiaquatic rodent swims with its large, webbed back feet and uses its naked tail as a rudder. Like the beaver, it lives in a group in a riverbank burrow or a lodge of twigs and mud.



- Up to 13 in (33 cm)
- Up to 12 in (30 cm)
- Up to 4 lb (1.8 kg)
- Small to large group
- Common

USA & Canada except tundra; introd. Eurasia

## FLUCTUATING LEMMINGS

Contrary to popular myth, Norway lemmings are not deliberately suicidal, but every 3 or 4 years, their number rises. Intolerant of one another at the best of times, the lemmings become highly aggressive. Such conflicts may trigger mass movements from the crowded alpine tundra to lower forests. When the lemmings meet obstacles such as rivers, panic can cause them to take flight, with some ending up in the sea.

***Fighting techniques*** lemmings may wrestle, box or adopt dominance postures.

## FACT FILE

**Smooth-tailed giant rat** This arboreal rat makes its nest in a tree hollow and is almost fully herbivorous, feeding mainly on shoots

- Up to 14½ in (37 cm)
- Up to 16 in (41 cm)
- Up to 3 lb (1.3 kg)
- Solitary
- Common

Central highlands of New Guinea

**Harvest mouse** One of the smallest mice, this species lives among tall crops, reeds, bamboo, or long grass. For each litter, both parents spend days building a globe-shaped nest that is suspended between stalks above the ground

- Up to 1 in (2.5 cm)
- Up to 1 in (2.5 cm)
- Up to ¼ oz (7 g)
- Solitary
- Near threatened

England & Spain to China, Korea & Japan

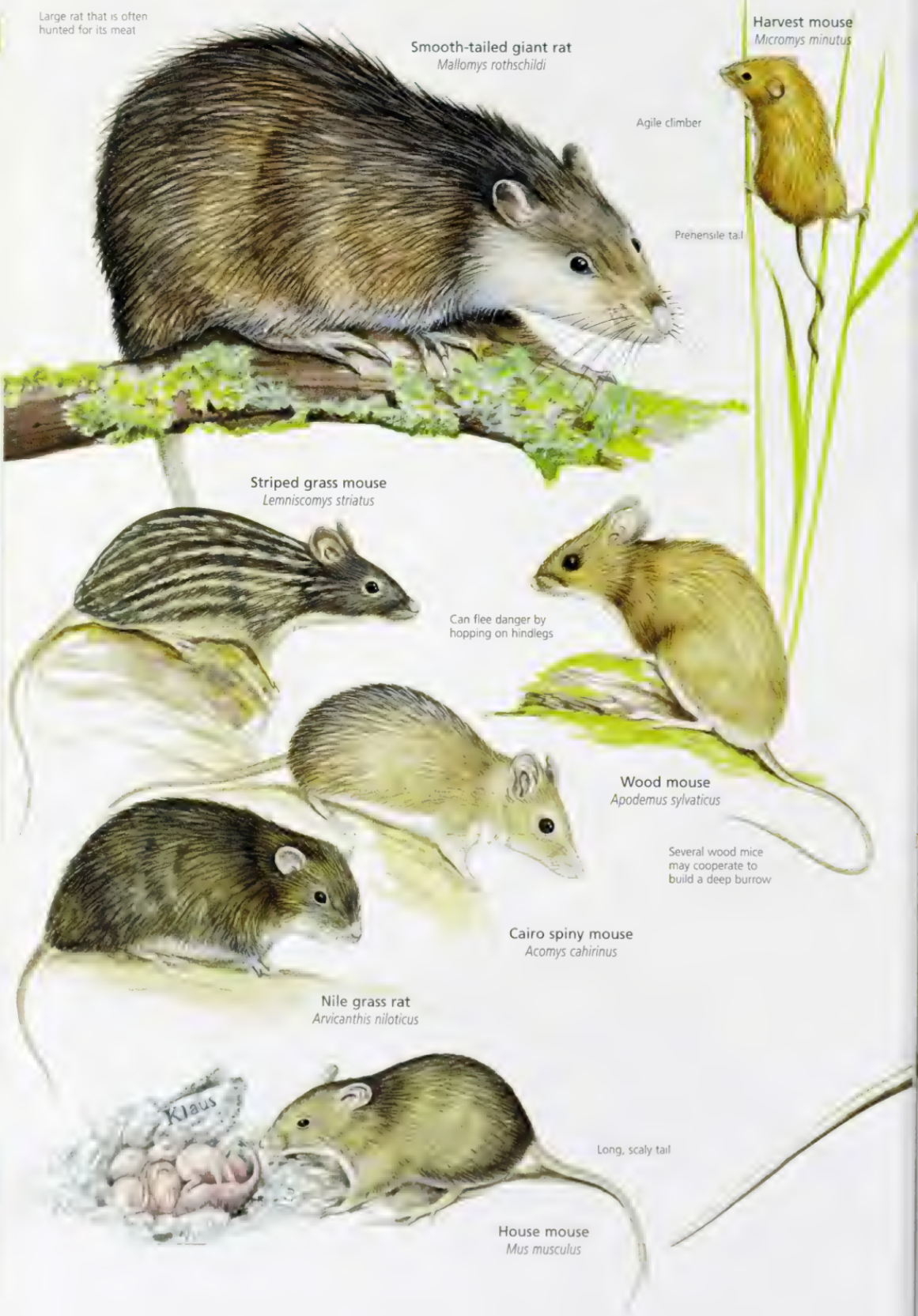
**Striped grass mouse** This savanna resident shelters in an underground burrow or an abandoned termite nest It builds a roundish nest for its litters, which are born during the rainy season after a gestation of 28 days

- Up to 5½ in (14 cm)
- Up to 6 in (15 cm)
- Up to 2½ oz (68 g)
- Solitary
- Common

Sub-Saharan Africa

**House mouse** Through its association with humans, this species has been able to spread throughout the world It nests in buildings or nearby fields and will eat almost any human food as well as items such as glue and soap.

- [illegible]
- [illegible] in (10 cm)
- [illegible]
- [illegible]
- [illegible]



Greater stick-nest rat
*Leporillus conditor*

Builds house of sticks as shelter from desert heat

Black rat is most often black but can be brown

Black rat
(roof rat, ship rat)
*Rattus rattus*

Brown rat
(Norway rat)
*Rattus norvegicus*

Short-tailed bandicoot rat
*Nesokia indica*

Feet adapted for climbing

Greater bandicoot rat
*Bandicota indica*

Natal multimammate mouse
*Mastomys natalensis*

Head and body can measure up to 17½ inches (45 cm)

Giant rat
*Cricetomys gambianus*

Cheek pouches for carrying food and nest material

## FACT FILE

**Greater stick-nest rat** Once found throughout the shrublands of southern Australia, this small rat became extinct on the mainland when rabbits and sheep overgrazed their habitat. Various reintroduction campaigns are underway

Up to 10 in (26 cm)
Up to 7 in (18 cm)
Up to 16 oz (450 g)
Family group
Endangered

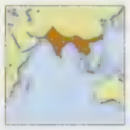
Franklin I. (Australia); reintrod. in several sites
Former range

**Short-tailed bandicoot rat** This nocturnal burrowing species will raid crops and lawn grass for food It stockpiles food in its burrow

Up to 8½ in (21 cm)
Up to 5 in (13 cm)
Up to 6 oz (175 g)
Solitary
Abundant

Egypt, Palestine & Syria to N. India

**Greater bandicoot rat** Found in both cultivated and urban areas, this species is considered a serious pest. It lives alone in a complex burrow system



Up to 14 in (36 cm)
Up to 11 in (28 cm)
Up to 3½ lb (1.5 kg)
Solitary
Abundant

S. Asia to China & S.E. Asia

## RATS AS PESTS

Along with the house mouse, the black rat and the brown rat have had a close relationship with humans, living off crops and stored food. In the process, they have caused untold damage and spread serious disease, including the bubonic plague, which killed a third of Europe's population in the Middle Ages. Both rats live in large packs, with up to 60 black rats and 200 brown rats to a pack, and will vigorously defend their feeding area from intruders Brown rats will eat almost anything and may even attack rabbits or human babies

***Disease carriers*** *By spreading disease, the brown rat has caused more deaths than all the wars in history*

## FACT FILE

**Gray climbing mouse** With its long, prehensile tail, this little mouse can easily climb the grasses and shrubs of its savanna home. It may dig a simple burrow to shelter from seasonal fires, but more often occupies a globe-shaped grass nest above the ground

Up to 2¾ in (7 cm)
Up to 3 in (8 cm)
Up to ¼ oz (8 g)
Solitary
Common

Sub-Saharan Africa

**Vlei rat** Like voles and lemmings, this rat lives in moist grassland, and tunnels through the grass to its feeding areas It will enter water to escape predators

Up to 8⅞ in (22 cm)
Up to 4⅓ in (11 cm)
Up to 6⅞ oz (180 g)
Solitary
Locally common

S Africa

**Fawn hopping mouse** If startled, this nocturnal burrower will bound away on its long hindlegs. Its urine is highly concentrated to help conserve water.

Up to 4¾ in (12 cm)
Up to 16½ in (16 cm)
Up to 1¾ oz (50 g)
Family group
Near threatened

Gibber desert of C. Australia

## WATER RAT

The Australian water rat lives in burrows that run along the banks of rivers or lakes. Able to withstand pollution, it is often found in urban areas. It depends on fresh water for the bulk of its diet, which includes crustaceans, mollusks, and fish. Broad, webbed feet act as paddles in the water. Its coat is not waterproof, but a pad of fat helps keep the heart warm

Up to 15½ in (39 cm)
Up to 12½ in (32 cm)
Up to 2½ lb (1.2 kg)
Solitary
Locally common

Australia & Tasmania

***Aquatic predator*** *The water rat often takes its catch to a preferred feeding platform*

Fat dormouse
*Myoxus glis*

Squirrel-like body and tail

Highly arboreal with short, curved claws for climbing

Garden dormouse
*Eliomys quercinus*

Forest dormouse
*Dryomys nitedula*

Flattened, bushy tail

Northern three-toed jerboa
*Dipus sagitta*

Woodland dormouse
*Graphiurus murinus*

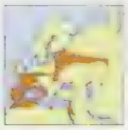
Lesser Egyptian jerboa
*Jaculus jaculus*

Meadow jumping mouse
*Zapus hudsonius*

Long tail provides stability when hopping

## FACT FILE

**Garden dormouse** This noisy rodent lives in large colonies, making globe-shaped nests of leaves and grass in tree hollows, among shrubs, or in rock crevices. As well as eating acorns, nuts, and fruit, it hunts insects and small rodents and birds.



Up to 6½ in (17 cm)
Up to 5 in (13 cm)
Up to 4 oz (120 g)
Colonial
Vulnerable

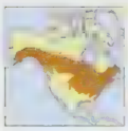
Europe

**Lesser Egyptian jerboa** With back legs four times longer than its front legs, this solitary desert animal will hop its way out of danger. It spends the day in a burrow, plugging the entrance with dirt during summer to create a cooler, humid microclimate.

Up to 4 in (10 cm)
Up to 5 in (13 cm)
Up to 2 oz (55 g)
Solitary
Not known

Morocco & Senegal to S.W. Iran & Somalia

**Meadow jumping mouse** Although it usually moves in short hops, this mouse can leap up to 3 feet (1 m) in the air when startled. It breeds very soon after emerging from its winter hibernation.



Up to 4 in (10 cm)
Up to 5 in (13 cm)
Up to 1 oz (30 g)
Solitary
Locally common

N. & E. North America

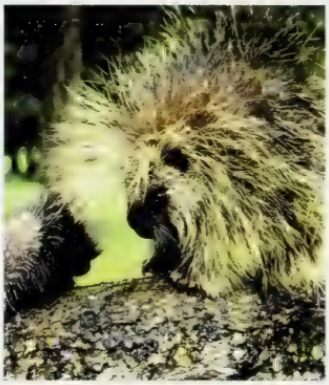
## WINTER SLEEP

The dormice of Europe prepare for their long winter hibernation by laying down a layer of fat on their body and stockpiling food in their nest or burrow. Depending on the climate, they can spend up to 9 months of the year asleep. They start mating as soon as they emerge from hibernation.

# CAVY-LIKE RODENTS

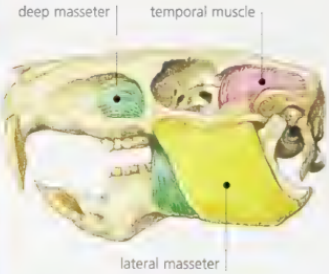
CLASS Mammalia
ORDER Rodentia
FAMILIES 18
GENERA 65
SPECIES 218

With their large heads, plump bodies, small legs, and short tails, the cavies of the Caviidae family—more commonly known as guinea pigs—are typical of cavy-like rodents. There are exceptions to this general body plan: some cavy-like rodents, such as the spiny rats of the Echimyidae family, look more like common mice and rats. All cavy-like rodents share a distinctive arrangement of the jaw muscles that gives them a strong forward bite. Unlike most other rodents, they also tend to have small litters of well-developed young. There are cavy-like rodents in both the Old World and the New World, but their relationship continues to be debated.



**Spiky young** New World porcupines, like other cavy-like rodents, give birth to well-developed young and have low infant mortality rates. Newborns have open eyes, can walk almost straight away, and are able to climb trees within a few days

**Rat-like form** The spiny rats of the family Echimyidae look more like the common mice and rats of Muridae than most other cavy-like rodents. If grabbed by a predator, a spiny rat's tail will break off, allowing it to quickly escape




**Powerful bite** Like squirrel-like rodents, cavy-like rodents have a strong forward bite, but it is produced by a different arrangement of the jaw muscles. The lateral masseter closes the jaw, while the deep masseter extends past the eye and pulls the jaw forward for biting.

**Living in pairs** The mara or Patagonian cavy (*Dolichotus patagonum*) is unusual among mammals in maintaining a lifelong monogamous pair bond. One member of the pair watches for danger while the other feeds. Different pairs of maras rarely interact, but they do share a communal burrow, [illegible] den, where young are visited daily by their parents for nursing

## CONSERVATION WATCH

Of the 218 species of cavy-like rodents, 33% are listed on the IUCN Red List, as follows

- 12 Extinct
- [illegible] Critically endangered
- [illegible] Endangered
- [illegible] Vulnerable
- [illegible] Near threatened
- [illegible] Data deficient

## CAVIES AND THEIR KIN

Although controversy persists as to whether the South American cavy-like rodents came from North America or rafted over from Africa, most of today's cavy-like rodents are found in Central and South America. The cavies of Caviomorpha include not only guinea pigs and similar species, but also the deer-like mara, a long-legged grazer. The semiaquatic capybara is more than 3 feet (1 m) long, making it the largest of all rodents. Chinchillas and viscachas live mainly at high elevations, kept warm by a thick, soft coat. Agoutis have long, slender limbs that allow them to run swiftly from danger. While most of South America's cavy-like rodents are terrestrial, tuco-tucos dig complex burrows. Other South American cavy-like rodents include degus, hutias, pacas, coypu, and pacarana.

New World porcupines, found in both North and South America, are arboreal and climb trees with agility, aided in some species by a prehensile tail. They share many features with the Old World porcupines of Africa, Asia, and Europe, but the latter are mostly ground-dwelling.

As well as porcupines, the Old World's cavy-like rodents include the African mole-rats, cane rats, and dassie rat. The gundis of North Africa (family Ctenodactylidae), have cavy-like jaw muscles, but are now classified in the suborder Sciurognathi. All other cavy-like rodents are now grouped together in the suborder Hystricognathi.

Bristle-like fur

Thumps ground with hindfeet and whistles when alarmed

Greater cane rat
*Thryonomys swinderianus*

Large bamboo rat
*Rhizomys sumatrensis*

Uses claws and teeth to dig burrow network

Dassie rat
*Petromus typicus*

Bristles on back feet used for grooming

Lesser mole-rat
*Nannospalax leucodon*

Cape dune mole-rat
*Bathyergus suillus*

Sensory whiskers on face and tail

Hair between toes acts as broom

Naked mole-rat
*Heterocephalus glaber*

## FACT FILE

**Greater cane rat** This robust nocturnal rodent eats mainly grasses and cane, and lives in small family groups. When threatened, it grunts and stamps its hindfeet, or runs into water. It is a good swimmer and diver

Up to 24 in (60 cm)
Up to 7½ in (19 cm)
Up to 10 lb (4.5 kg)
Small groups
Locally common

C. & S. Africa

**Dassie rat** With its flattened skull and flexible ribs, this rock-dweller can squeeze itself into a crevice to hide from predators. Females even have nipples on their sides so young can continue to nurse while hiding.

Up to 8½ in (21 cm)
Up to 6 in (15 cm)
Up to 7½ oz (210 g)
Pair, family group
Not known

S.W. Angola, Namibia, South Africa

## COOPERATIVE COLONY

Naked mole-rats survive in arid regions of Ethiopia, Somalia, and Kenya by living underground in highly structured colonies of about 70 animals. As with social insects such as ants and bees, a single female mole-rat known as the queen and a few males do all the breeding. The other adults are either workers or soldiers, and do not produce young, even though they are fertile. Workers, which tend to be the smaller members, dig burrows and take food to the communal nest. The larger soldiers rest in the nest until required to defend the colony. The queen's young are cared for by all the members of the colony

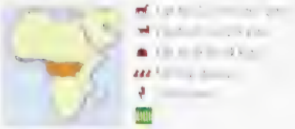
*Diggers*

## FACT FILE

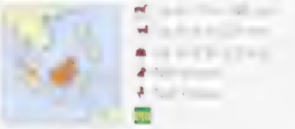
**Old World porcupines** These porcupines are generally terrestrial and their [illegible] and crested [illegible] black and white [illegible] that rattles.

**Crested porcupine** This porcupine [illegible] known to kill lions, hyenas, and [illegible]. When threatened, it raises its quills to make itself seem larger, but if [illegible] that the [illegible] be [illegible].

**African brush-tailed porcupine** This species lives in a family group made up of a breeding pair and anyone offspring. They spend the day together [illegible] and [illegible] for [illegible].



**Long-tailed porcupine** [illegible] Old World porcupines. This [illegible] quills [illegible] and [illegible] and [illegible] and other [illegible].



## CONSERVATION WATCH

**Spiky protection** With their spines forming effective armor, porcupines have few natural predators. They are, however, killed by humans for food, sport, and pest control. Most species are common, but the Malayan porcupine is listed as vulnerable and the crested porcupine and the thick-spined porcupine (*Hystrix crassispinis*) are considered near threatened.

Brazilian porcupine
*Coendou prehensilis*

North American porcupine
*Erethizon dorsatum*

Up to 30,000 sharp barbed quills

Prehensile tail lacks spines

Bicolor prehensile-tailed porcupine
*Coendou bicolor*

Stump-tailed porcupine
*Echinoprocta rufescens*

Naked pad on underside of tail for grip

Male has scent gland on snout

Can swim with just eyes, nose, and ears protruding, or stay fully submerged for up to 5 minutes

Capybara
*Hydrochaeris hydrochaeris*

Webbed feet for swimming

## FACT FILE

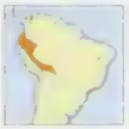
**New World porcupines** Aided by large, gripping feet with strong and naked soles, these porcupines can climb trees. They have poor eyesight but good senses of smell and hearing.

**North American porcupine** This species dens in a cave, rock crevice or fallen log, emerging at night to browse on the bark of trees and shrubs.

Up to 3/ ft
Up
Up to 39/ lb (18
Solitary
Locally c

N. & W. North America

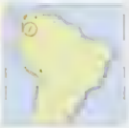
**Bicolor prehensile-tailed porcupine** A long, gripping tail helps this species clamber through the middle and upper layers of the forest. It climbs down to the ground only occasionally.



Up to 19/ in (49 cm
Up to 21 in (54 cm
Up to 10/ lb (4.7 kg)
Pair
Locally commo

E. foothills of Andes from Colombia to Bolivia

**Stump-tailed porcupine** This little-studied species has a short, hairy tail. Its spines become thicker and shorter toward the rear.



Up to 14/ in (37 cm)
Up to 6 in (15 cm
Not known
Not known
Not known

Andes in Colombia

## THE BIGGEST RODENT

Capybaras are barrel-shaped grazers that feed mainly on grasses growing in or near water. They enter the water to seek refuge from the midday heat, to escape predators, and to mate. These social animals usually live in groups of one male, several females and their young, but in dry times may form larger temporary herds of up to a hundred individuals.

## FACT FILE

**Paca** This solitary creature spends the day in a shallow burrow. It is hunted for its meat and as an agricultural pest and has lost much of its forest habitat.

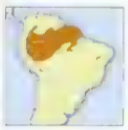
Up to 30½ in (78 cm)
Up to 1 in (3 cm)
Up to 28½ lb (13 kg)
Pair
Common

Mexico to S. Brazil & N. Paraguay

### AGOUTIS AND ACOUCHIS

The young of agoutis and acouchis are born after a relatively long gestation period of approximately 100 days They emerge fully furred and with their eyes open. Within hours, they are able to run and will nibble on green plants. Even so, they continue to drink their mother's milk for some weeks. Their potential lifespan is long, up to 17 years, but most do not make it through their first year, falling prey to predators such as coatis or starving during the dry season

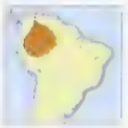
**Red acouchi** Active by day, the red acouchi will bury some food during times of abundance. This ensures the animal a food supply in leaner times, but also helps to disperse seeds throughout the forest



Up to 15½ in (39 cm)
Up to 3 in (8 cm)
Up to 3½ lb (1.5 kg)
Solitary
Data deficient

S. Colombia to Guianas, Amazon basin

**Gray agouti** This species can leap more than 6 feet (2 m) in the air. It walks on its digits and will gallop when in a hurry. Courtship involves the male spraying the female with urine, causing her to make frenzied movements



Up to 30 in (76 cm)
Up to 1½ in (4 cm)
Up to 13 lb (6 kg)
Solitary, pair
Common

**Brazilian agouti** As in other agoutis [illegible] part of this animal is slender [illegible] rear is bulkier, an adaptation [illegible]

Up to 1 in (3 cm)
[illegible]

Demarest's hutia
*Capromys pilorides*

Hairy tail

Hispaniolan hutia
*Plagiodontia aedium*

Scaly tail

Prehensile-tailed hutia
*Mysateles prehensilis*

Brown's hutia
*Geocapromys brownii*

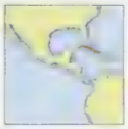
Coypu (nutria)
*Myocastor coypus*

Fringes of bristles on hindfeet used for grooming

White-bellied tuco-tuco
*Ctenomys colburni*

## FACT FILE

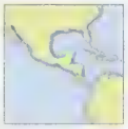
**Demarest's hutia** While this species has strong claws and easily climbs trees, it spends more time on the ground than most other hutias. It shares with other hutias a stomach divided into three compartments, the most complex stomach of any rodent



Up to 24 in (60 cm)
Up to 12 in (30 cm)
Up to 18½ lb (8.5 kg)
Pair
Common, declining

Cuba & adjacent offshore islands

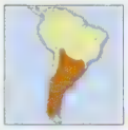
**Brown's hutia** This terrestrial animal usually lives alone, but can be found in family groups of up to 10 animals. It hides in rock crevices by day, but waddles out at night to search the forest for leaves, roots, bark, and fruit.



Up to 17½ in (45 cm)
Up to 2½ in (6 cm)
Up to 4½ lb (2 kg)
Not known
Vulnerable

Jamaica

**Coypu** Equally at home in salt and fresh water, this semiaquatic species swims with its webbed hindfeet and can stay submerged for 5 minutes. It eats aquatic plants and shellfish.



Up to 25 in (64 cm)
Up to 16½ in (42 cm)
Up to 22 lb (10 kg)
Pair, family group
Common

Bolivia & Brazil to Patagonia, introd. elsewhere

**White-bellied tuco-tuco** This robust burrower digs tunnels with the strong claws on its forefeet, cutting through any roots with its prominent incisors. Considered a pest, it has been hunted in great numbers.

Up to 6½ in (17 cm)
Up to 3 in (8 cm)
Not known
Not known
Not known

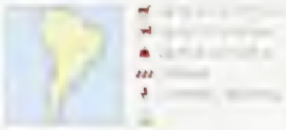
Known from only two localities in Argentina

## CONSERVATION WATCH

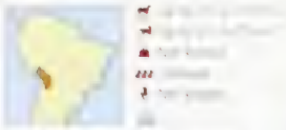
**Vanishing hutias** Living only in the West Indies, the hutias of the Capromyidae family are hunted intensively for food. They also fall prey to birds, snakes, and introduced domestic animals. In recent times, six species of hutia have become extinct and a further six are critically endangered, four are vulnerable, and two are near threatened.

## FACT FILE

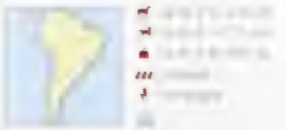
**Coruro** Living in complex burrows [illegible]

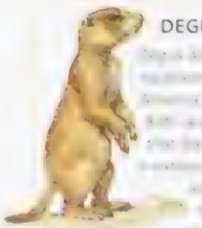


**Chinchilla-rat** This little rodent [illegible]



**Chinchilla** [illegible]





### DEGUS AND DOGS

[illegible]

## CONSERVATION WATCH

**Hunted chinchillids** Prized for their soft fur, the chinchillas and viscachas [illegible] have been [illegible] In 1900 [illegible]

Coruro
*Spalacopus cyanus*

Degu
*Octodon degus*

Chinchilla-rat
*Abrocoma cinerea*

Chilean rock rat
*Aconaemys fuscus*

Large ears listen for predators

Chinchilla
*Chinchilla lanigera*

Peruvian mountain viscacha
*Lagidium peruanum*

Striped face unusual among rodents

Plains viscacha

# LAGOMORPHS

CLASS Mammalia
ORDER Lagomorpha
FAMILIES 2
GENERA 15
SPECIES 82

The rabbits, hares, and pikas of the order Lagomorpha were once considered a suborder of Rodentia, and they do bear some resemblance to large rodents. They are gnawing herbivores, with large, constantly growing incisors, no canine teeth, and a gap between the incisors and molars. Like rodents, they can close their lips in this gap and gnaw on material without taking it into the mouth. Unlike rodents, they have a second, smaller pair of upper incisors, known as peg teeth, behind the first pair. All lagomorphs are terrestrial. They are found almost worldwide in a diverse range of habitats, from snowy arctic tundra to steamy tropical forest and scorching desert.

**In human company** While their close association with humans has allowed lagomorphs to spread almost worldwide they are absent from southern South America and many islands. Where they have been introduced, as in Australia and New Zealand, lagomorphs have often had a devastating effect, outcompeting both native animals and livestock for food

**Boxing hares** Throughout the mating season, male Arctic hares compete for access to females, while each female fends off any males that she is not interested in. Arctic hares most often live in small family groups, but larger bands of more than a hundred individuals can occur, especially on cold, northern islands.

**Harvesting pika** During summer and fall, most pikas prepare for winter, spending up to a third of their time gathering grasses, leaves, and flowers in their mouth and adding them to a haystack sheltered under an overhanging rock.

**Fleet of foot** With their long, powerful hindlimbs, hares are designed to outrun their predators and have been known to exceed speeds of 45 miles per hour (70 km/h). Even at full speed, these agile animals can abruptly change direction

### CONSERVATION WATCH

While a few lagomorph species have become pests, many specialized ones are suffering. Of the 82 species of lagomorphs, 37% are listed on the IUCN Red List, as follows:

- 1 Extinct
- 4 Critically endangered
- 7 Endangered
- 6 Vulnerable
- 8 Near threatened
- 4 Data deficient

## RABBITS, HARES, AND PIKAS

Lagomorphs are divided into two families: the rabbits and hares of Leporidae, and the pikas of Ochotonidae. As key prey species for many birds and carnivores, all lagomorphs have eyes on the side of the head that provide a wide field of vision, and relatively large ears that contribute to their sharp hearing. In pikas, the ears are short and round, while rabbits and hares have very long ears.

Many lagomorphs are social species, and all use their scent glands in communication. In pikas, these are supplemented by a variety of vocalizations, which inspired their nickname of "calling hares."

To escape predators, both rabbits and hares have long hindlegs that allow them to run at speed—rabbits tend to flee to cover, while hares try to outrun the danger over open ground. Pikas have shorter legs, but usually live in rocky terrain where they can quickly slip into a crevice.

In spite of their anti-predator tactics, all lagomorph species are an important food source for other animals and suffer a high mortality rate. To cope with this, they tend to be prolific breeders. Gestation periods are short, usually lasting just 30–40 days, and litters are often large. Many species reach sexual maturity quickly—female European rabbits can breed at only 3 months. The female's eggs are released in response to copulation, and she is able to become pregnant almost immediately after giving birth. In some species, the female can conceive [illegible] still pregnant with the first. This reproductive strategy has allowed some species, such as the European rabbit, to become so successful that they are considered pests.

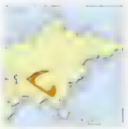
## FACT FILE

**Northern pika** Active through long, cold winters, this species stays on the surface until the snow cover is about 12 inches (30 cm) deep, and then retreats into tunnels under the snow.

Up to 8 in (20 cm)
None
Up to 7 oz (200 g)
Solitary
Not known

Mongolia, Siberia

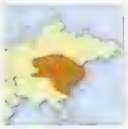
**Royle's pika** Although this pika normally nests in natural rock piles, it has been known to live in the rock walls of huts built by humans. Because it forages throughout the year, it does not create a haystack as other pikas do.



Up to 8 in (20 cm)
None
Up to 7 oz (200 g)
Solitary
Not known

Himalayas of Pakistan, India, Nepal & Tibet

**Daurian pika** This steppe-dweller is a highly social burrower, living in large colonies made up of family groups. Family members communicate through a repertoire of calls, groom each other, rub noses, and play together.



Up to 8 in (20 cm)
None
Up to 7 oz (200 g)
Colonial
Common

Steppes of Mongolia & S. Siberia

**American pika** Each American pika defends an area of rock, with males and females occupying adjacent but separate territories.

Up to 8½ in (22 cm)
None
Up to 6 oz (175 g)
Solitary
Locally common

W. North America

## CONSERVATION WATCH

**Keystone species** Considered pests because of their large numbers and burrowing habit, the plateau pikas (*Ochotona curzoniae*) of the Tibetan plateau have been the target of poisoning campaigns. Such measures ignore the key role the pikas play in their ecosystem. Not only do they serve as prey for many predators, but their burrows are used for shelter by many birds and lizards, and their digging increases plant diversity and minimizes erosion.

Large-eared pika
*Ochotona macrotis*

Nostrils can be completely closed

Northern pika
*Ochotona alpina*

Turkestan red pika
*Ochotona rutila*

Calls include a one- or two-note squeak that expresses fear

Royle's pika
*Ochotona roylei*

Daurian pika
*Ochotona daurica*

Two main vocalizations are an alarm call and a mating song

Steppe pika
*Ochotona pusilla*

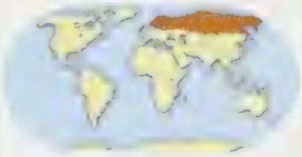
American pika
*Ochotona princeps*

Heavily furred feet

## FACT FILE

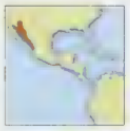
**Arctic hare** To survive the harsh Arctic winter, this usually solitary hare may gather in flocks of several hundred individuals, and smaller groups may cooperate to build a protective wall of snow. The Arctic hare also changes color with the season, growing a white winter coat to blend in with the snow, then shedding this for a brown coat to match the summer tundra vegetation.

- Up to 24 in (60 cm)
- Up to 3 in (8 cm)
- Up to 13 lb (6 kg)
- Solitary
- Common



Iceland, Ireland, Scotland, N. Eurasia

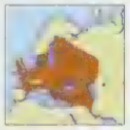
**Antelope jackrabbit** Like an antelope, this large hare is able to make great leaps. A desert species, it is nocturnal and can survive without drinking water, obtaining all its water from plants.



- Up to 24 in (60 cm)
- Up to 3 in (8 cm)
- Up to 13 lb (6 kg)
- Solitary
- Common, declining

S. Arizona to N. Mexico

**Brown hare** Female brown hares can produce four litters a year. For the first month, the young are left in a form, a shallow depression in long grass, and visited once a day for feeding.



- Up to 27 in (68 cm)
- Up to 4 in (10 cm)
- Up to 15½ lb (7 kg)
- Solitary
- Common, declining

Europe to Middle East; introd. widely

## COOL EARS

A resident of North America's deserts, the black-tailed jackrabbit relies on its long ears to keep cool. Hundreds of tiny blood vessels radiate heat to the surface of the ears, allowing the blood to cool before it returns to the heart. A jackrabbit spends the hottest part of the day resting in the shade of a shrub or long grass

## FACT FILE

**Eastern cottontail** This solitary rabbit spends the daytime resting in a hollow beneath a log or brush. Although blind and naked at birth, young cottontails can leave the nest at 2 weeks of age, disperse at 7 weeks, and are sexually mature at only 3 months

Up to 19½ in (50 cm)
Up to 2½ in (6 cm)
Up to 3½ lb (1.5 kg)
Solitary
Common

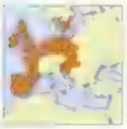
E. & S. North America

**Pygmy rabbit** The smallest rabbit, this species lives amid dense sagebrush, which forms much of its diet, and digs its own burrow. It emits a distinctive whistle to warn neighbors of danger.

Up to 11 in (28 cm)
Up to ¾ in (2 cm)
Up to 16 oz (460 g)
Solitary
Near threatened

W. USA

**European rabbit** Popular as a game animal, this species was deliberately introduced in many places, often with devastating effects on native fauna.



Up to 18 in (46 cm)
Up to 3 in (8 cm)
Up to 5 lb (2.2 kg)
Family group
Abundant

British Isles; Spain to Balkans; introd. widely

**Hispid hare** Hunting and domestic dogs have taken their toll, but this animal is most threatened by deliberate burning of its grassland habitat.

Up to 19½ in (50 cm)
Up to 1½ in (4 cm)
Up to 5½ lb (2.5 kg)
Solitary, pair
Endangered

Foothills of Himalayas in Nepal & N. India

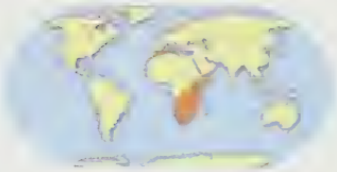
### RABBIT WARREN

The European rabbit is one of the few rabbit or hare species to dig its own burrow, and is the only one to live in stable, territorial breeding groups. Large numbers of young are raised in the shelter of an underground warren

# ELEPHANT SHREWS

**CLASS** Mammalia
**ORDER** Macroscelidea
**FAMILY** Macroscelididae
**GENERA** 4
**SPECIES** 15

Little studied until recent years and categorized at different times with insectivores, ungulates, tree shrews, and lagomorphs, elephant shrews are so distinctive that they are now placed in their own order, the Macroscelidea. Their long, mobile snout suggested an elephant's trunk to naturalists, inspiring their common name. They are ground-dwellers, relying on keen hearing and vision to detect danger, and on the speed provided by their long, slender legs to escape predators. Some smaller species move in leaps when alarmed, resembling miniature antelopes. Elephant shrews are insect-eaters, but have larger, more developed brains than the insectivores.



**African habitats** Elephant shrews are found throughout much of Africa, but are missing from West Africa and the Sahara Desert. They occupy diverse habitats, including rocky outcrops, desert, savanna, grasslands, thornbrush plains, and tropical forest. Although terrestrial and often active by day, these secretive, swift mammals are not common and are rarely seen

### INSECT-EATERS

An elephant shrew can spend up to 80 percent of its waking hours foraging. Although elephant shrews have a large cecum similar to that of herbivores and may include some fruit, seeds, and other plant matter in their diet, they are largely insectivorous, feeding mainly on invertebrates such as spiders, beetles, termites, ants, centipedes, and earthworms. Their long, sensitive, mobile snout can root around in leaf litter, detecting the small prey by smell. Some species use their claws and teeth to raid the tunnel systems of ants and termites. Like other elephant shrews, the bushveld elephant shrew (*Elephantulus intufi*) has a long tongue (shown above) that is able to speedily flick insects into its mouth.

**Together and alone** Like other elephant shrews, rufous elephant shrews live in monogamous pairs, usually mating for life. The pairs rarely meet, but share and defend exactly the same territory. They rely on scentmarking to communicate, and maintain a network of trails that allows fast escape from predators. Trespassing male elephant shrews are driven off by the male of the pair, while the female deters female intruders.

# BIRDS

# BIRDS

| | |
|---|---|
| PHYLUM | Chordata |
| CLASS | Aves |
| ORDERS | 29 |
| FAMILIES | 194 |
| GENERA | 2,161 |
| SPECIES | 9,721 |

Descended from reptiles that developed the ability to fly, birds are among the most mobile of all animals alive today. Most numerous in marshes, woodlands, and rain forests, they have also adapted to live in large cities, inhospitable deserts, and even the North and South poles. Some never stray from home; others cross entire oceans or continents, sometimes in a single flight. In size, they range from the tiny bee hummingbird to the imposing ostrich. Among the more than 9,700 species are birds of almost every color and a dazzling array of patterns. While some hover on the verge of extinction, others, such as domestic chickens, outnumber humans.

**Early bird** The first birds evolved from dinosaurs more than 150 million years ago. The oldest-known bird is the Archaeopteryx (above), the first fossil of which was discovered in Germany in 1861. It was a swift, two-legged predator whose feather-covered bod, was probably capable of powered flight.

## ON THE WING

Birds' flying and singing abilities have awed humans through the millennia. These distinctive animals have been the inspiration not only for the invention of mechanical flying machines, but also for myths, musical works, and other art forms.

Although some species of birds have lost the ability to fly, they all have feathers. In general, no other types of animals can travel so far or so fast under their own power.

Birds can perform an astonishing range of aerial maneuvers, from swooping and soaring to hovering or even, in some cases, flying backwards. They may fly to search for food and more favorable climates, or else to ward off predators or communicate with each other.

Some birds seek out territories for temporary breeding, roosting, or feeding purposes, while others spend their entire lives in one area. Many species of birds migrate over great distances to escape harsh winters before returning to their starting places when the weather begins to improve again. They are guided by instinct and experience.

Not all types of birds sing, but more than half of the species are considered songbirds. Some of these have very large repertoires, which are used primarily by males to court females and deter other males from their territories.

Some birds are solitary; others live in large flocks and may even help raise other parents' young.

More than 30 species of birds became extinct during the 20th century, mostly due to human activities. Today, one out of every nine species of birds is threatened, and many more species are in decline. Past species extinctions were mostly due to overhunting, as in the case of the passenger pigeon.

Today, habitat loss and destruction are by far the most serious factors in the decline of birdlife worldwide. Pesticides and other pollutants also take their toll, as do introduced species such as cats and rats, especially on populations of island birds that never evolved defenses against such animals.

Although many types of birds appear on the threatened list, parrots feature very prominently, because their bright feathers attract poachers and because they tend to live in tropical rain forests, which are disappearing at a fast rate.

***Spreading out***
*The wings are fully spread and thrust forward. The feathers overlap and the feet are tucked against the body*

***Pushing forward***
*The wings drop and the feathers dig into the air. This pulls the robin forward*

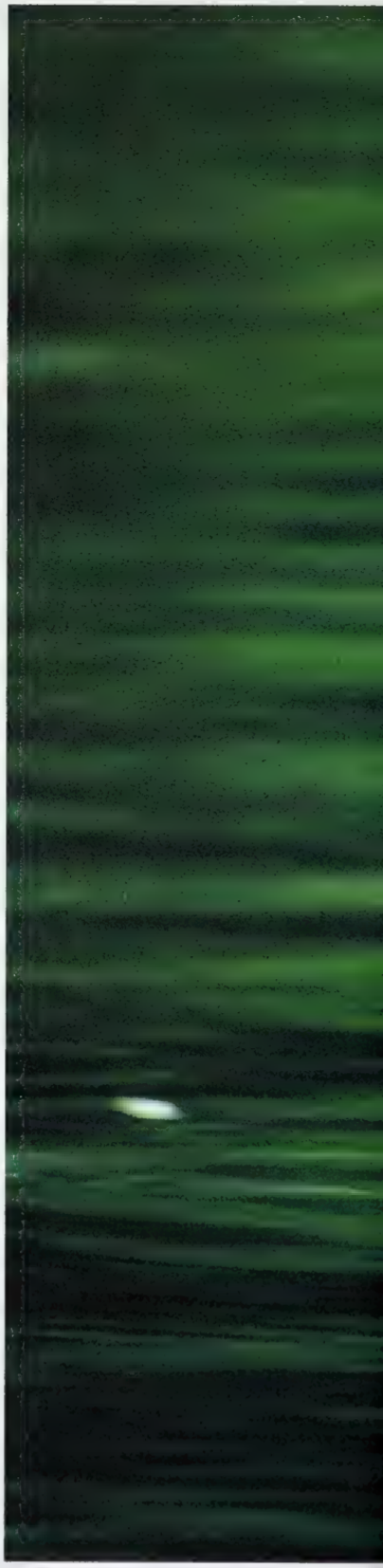
***Ending***
*The feathers twist apart as the downstroke ends*

***Tucking in***

***Beginning***

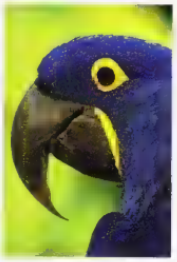
**On the wing**

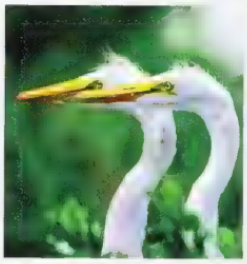
**Power in the air**



**A slow start** All birds hatch from eggs (left). One or both parents typically sit on the eggs to incubate them, keeping them warm enough to allow the embryos to develop. When it is ready, a chick frees itself by pecking a hole through the shell

**Courtship** Most birds are monogamous They attract mates and then cement their bonds in a variety of ways, including singing, displaying special breeding plumage, performing aerial acrobatics, or dancing, like these cranes (below)





**Bills of fare** A bird's bill can provide important clues to its lifestyle. Above, from left to right: a puffin's serrated bill helps it hold fishes; a macaw's can easily shell nuts and seeds; and an egret's is well suited to catching pond life in the rushes.

### FEATHER TYPES

There are three kinds of feathers. Closest to the body are the fluffy down feathers that protect a bird from the cold. Over these are the contour feathers. These are short and round, and give the bird its streamlined shape. The longer feathers on a bird's wing and tail enable the bird to take off, fly, maneuver, and land

***Flight feather*** *The vane of a flight feather is made up of fine strands that interlock to create a smooth surface*

***Purpose-built*** *Feathers provide warmth, protection and shape, as well as the dynamics that make flight possible*

## ENGINEERING MARVELS

Birds come in all shapes and sizes. Yet, although external features vary markedly among species, all birds share a remarkably similar anatomy. All birds are descended from flying ancestors and have front limbs in the form of wings. A flying bird's body is designed to enable it to move efficiently through the air. For example, most of a bird's weight is in the center of its body, which is light and strong, with fewer bones than the bodies of reptiles or mammals. Flight is a very demanding activity that requires a high metabolism, so the respiratory system and heart of birds are very efficient.

A bird's digestive tract is fairly typical of vertebrates, although some birds have a crop for the temporary storage of food (for subsequent grinding in the gizzard and for absorption through the intestine walls, or for regurgitation to feed the young.

Some avian features—such as the scales on their legs and feet and the laying of eggs—are reminiscent of their reptilian ancestors.

However, because birds are warm-blooded, they must spend a large part of their waking time searching for food. Their diets range from seeds and fruits to insects, small mammals, and even other birds.

Bills serve similar functions for birds as hands do for humans; their primary function is food gathering. There is enormous variation in the structure and shape of birds' bills and feet, reflecting the ecological niches species have adapted to fill.

The forms of a bird's wings and tail determine the amount of lift, thrust, and maneuverability it will have in flight. An improvement in one of these aspects can generally be achieved only with a sacrifice of performance in the other two. Small birds that need to fly off quickly to evade predators tend to have short wings; large birds such as albatrosses that regularly fly very long distances have long, thin wings for gliding.

Eyesight is birds' most well-developed sense, with hearing ranking second, despite the lack of any external ear structure.

Birds' feathers come in many colors (which may vary with the seasons) and are

**Looming large** The ostrich (*Struthio camelus*) (right) is the world's largest bird Unlike most birds, it has shaggy feathers and cannot fly. The group to which the ostrich belongs is also unusual among birds for having a flat sternum

frequently used for social displays as well as for flying. Males tend to be more colorful than females.

To keep feathers in fine shape, birds preen regularly, running their beaks along the length of their feathers to smooth them out and to remove foreign particles. But even the most well-tended bird's feathers eventually become old and tattered, so at least once a year birds shed their feathers and grow new ones in a process known as molting. Birds also clean themselves by bathing in water or dust.

Most birds build nests to house their young. They lay from one to a dozen or more eggs, either once or several times a year.

Some species are born well-developed enough to fend for themselves right away; others are born blind and helpless. Until they are strong enough to fly and be independent, they remain in the nest, relying on one or both of their parents for food and for protection from predators. This nestling period can range from about a week to more than 5 months.

**Controlled chaos** This flock of snow geese (*Chen caerulescens*) (above) may look chaotic, but the birds can sense their neighbors and maneuver quickly to avoid bumping into each other, very much like human commuters on busy city streets.

**Keeping warm** Birds such as the northern cardinal (*Cardinalis cardinalis*) (left) that don't live in or migrate to warmer climates struggle to find enough food and maintain a constant body temperature during the winter months. Fluffing up their feathers traps air and helps insulate their bodies.

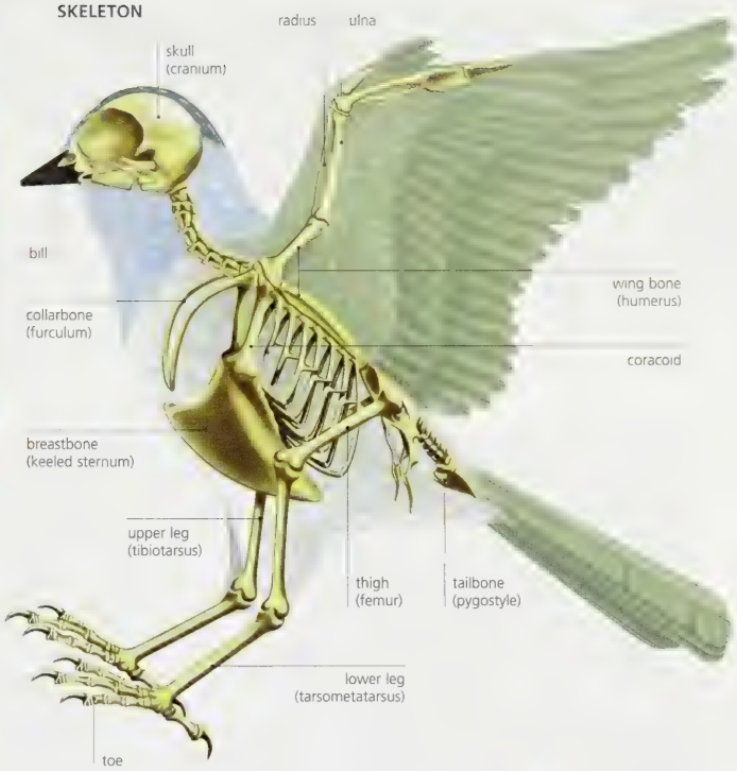
**Adapted to flight** A bird's skeleton (right) is typical of vertebrates, with modifications to support powered flight. Parts of the backbone are fused into a sturdy frame. The collarbone is fused into a furculum (commonly known as a wishbone). As the bird flies, this bone acts like a spring. The breastbone, or sternum, is broad and curved to provide a secure anchor for the strong flight muscles. Lungs continuously transfer oxygen to the blood, which the powerful heart pumps to the muscles.

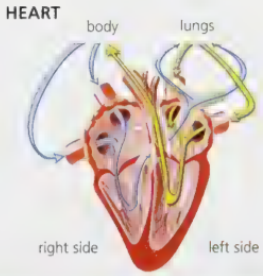
**Disappearing act** One of the hundreds of threatened birds is the harpy eagle (*Harpia harpyja*) (right), the world's most powerful bird of prey, which is in dangerous decline in the tropical forests of Central and South America. The majority of threatened bird species live in developing countries.

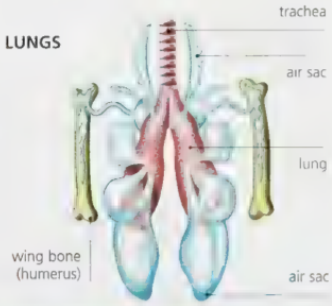
### CONSERVATION WATCH

The 2,139 species of birds on the IUCN Red List are categorized as follows:

| | |
|---|---|
| 129 | Extinct |
| 3 | Extinct in the wild |
| 182 | Critically endangered |
| 331 | Endangered |
| 681 | Vulnerable |
| 3 | Conservation dependent |
| 731 | Near threatened |
| 79 | Data deficient |



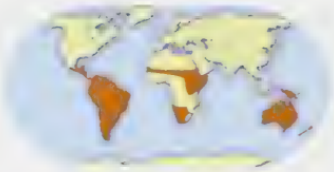



# RATITES AND TINAMOUS

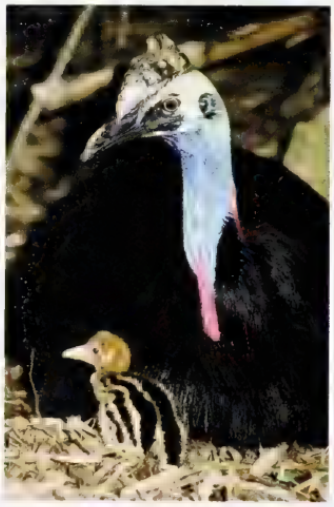
CLASS Aves
ORDERS 5
FAMILIES 6
GENERA 15
SPECIES 59

Ratites are flightless birds with flat sternums, or breastbones, that lack the prominent, keel-like sternums of flying birds. Like other flightless birds, they are believed to have lost the ability to fly because they either lacked predators or could evade them by less energy-intensive means. This category includes two groups of large extinct birds, the moa of New Zealand and the elephant bird of Madagascar. Most ratites are believed to have evolved along similar lines rather than from one distinct ancestor. Tinamous are a related order of flying birds with keeled sternums that share some unusual anatomical characteristics—such as a distinctive palate structure—with ratites.



**Southern exposure** Ratites and tinamous are found only on southern Gondwanan continents. The various species are adapted to grasslands, jungles, woodlands, or high mountain ranges. The emu is the most versatile, roaming in diverse habitats

**Courting** A reversal of the usual sex roles is apparent among tinamous (above), with the females taking the more aggressive lead role in courtship.



**Fathers lead** Like most other ratites and tinamous, the male cassowary (above, right) is responsible for incubating and raising the young. Male emus lives off their fat reserves for the entire 8-week incubation period, not taking a break to eat, drink, or even defecate during that time

## GIANTS AND RUNNERS

Adult ratites and tinamous—among them the largest of all birds, the ostrich, which may exceed 9 feet (2.8 m) in height—resemble overgrown chicks, with underdeveloped, stubby wings and soft flight feathers.

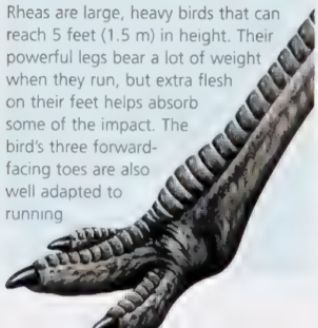
Powerful runners, ratites have as few as two toes per foot, rather than the standard four toes of other birds. Ostriches can run faster than a racehorse and sometimes defend themselves by kicking. Rheas, sometimes called South American ostriches, occasionally raise one of their wings while running, but in this case the front limb serves the function of a sail rather than a wing.

The kiwis of New Zealand have vestigial wings. These three species of nocturnal birds—the country's national symbol—live in burrows and find their invertebrate prey by scent, using their long, sensitive bills. They are one of the few birds with a good sense of smell.

Tinamous are an ancient order of diverse, abundant smaller birds with plump bodies, short, rounded wings, and loose plumage. Some of the 47 species roost in trees, others on the ground. Although tinamous can fly, they usually escape predators by stealing through cover or by freezing.

### PADDING ALONG

Rheas are large, heavy birds that can reach 5 feet (1.5 m) in height. Their powerful legs bear a lot of weight when they run, but extra flesh on their feet helps absorb some of the impact. The bird's three forward-facing toes are also well adapted to running



Broad, flat bill for feeding on seeds and fruit

Ostrich
*Struthio camelus*

Contrastingly colored tail is raised and fanned in display

Lesser rhea
*Pterocnemia pennata*

The only ratites in Africa, ostriches have only two toes

♂

♀

Rheas, like tinamous, live only in South America

Emus, like cassowaries, have twinned hairy feathers

Greater rhea
*Rhea americana*

Long neck for reaching food

Emu
*Dromaius novaehollandiae*

Northern cassowary
*Casuarius unappendiculatus*

Southern cassowary
*Casuarius casuarius*

Powerful short legs are well adapted for running through rain forest

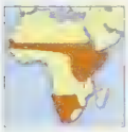
Brown kiwi
*Apteryx australis*

Little spotted kiwi
*Apteryx owenii*

Kiwis, found only in New Zealand, have sensory nostrils at the tip of the bill

## FACT FILE

**Ostrich** This large bird once ranged to the Middle East and Asia, but is now limited mainly to national parks in eastern and southern Africa. Males keep a temporary harem when breeding and scrape nests on the ground



Up to 9½ ft (2.9 m)
5–11 (major hen)
Sexes differ
Nomadic
Locally common

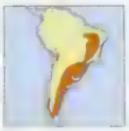
C., E. & S. Africa

**Emu** This species is the sole surviving member of its family. Adaptable birds, emus live in a variety of habitats. They form temporary pairs to mate, and walk vast distances in search of fruit, seeds, insects, and young shoots

Up to 6½ ft (2 m)
7–11
Sexes alike
Nomadic
Locally common

Australia, Tasmania (extinct)

**Greater rhea** The larger of two species of rhea, the greater rhea has a wide, flat beak that is well adapted for grazing on the plains where it roams. It is a very agile runner, able to twist and turn abruptly to elude its pursuers. Males fight for territory



Up to 5¼ ft (1.6 m)
13–30
Sexes alike
Sedentary
Near threatened

E., S.E. & C.W. South America

**Southern cassowary** Females of this secretive, solitary rain-forest species are larger and more brightly colored than the males, with taller casques atop their heads. Males rear the chicks

Up to 6½ ft (2 m)
3–5
Sexes alike
Sedentary
Vulnerable in Australia

Ceram, S. New Guinea, N.E. Australia

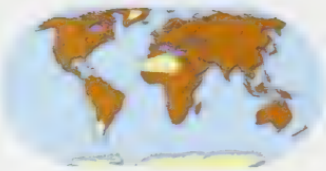
## CONSERVATION WATCH

**Ratites** IUCN lists two of the three species of cassowary as vulnerable, and all three species of kiwi as well. The emu is common enough on mainland Australia; but two flightless species that were alive on King and Kangaroo Islands off southeastern Australia, at the time of European settlement are now extinct

# GAMEBIRDS

| | |
|---|---|
| CLASS | Aves |
| ORDERS | 1 |
| FAMILIES | 5 |
| GENERA | 80 |
| SPECIES | 290 |

These familiar birds include chickens (domesticated forms of central Asian jungle fowl) and turkeys. Humans also hunt and eat pheasants, partridges, grouse, and quail. Peafowl are sometimes kept in captivity because of their beautiful plumage and ornate displays. These birds vary widely in size, but they all have stocky frames, relatively small heads, and short, broad wings. They typically fly low and fast. They are a favorite prey animal of many wild predators. To elude them, gamebirds rely on the camouflage effect of their dull-colored plumage, or else they fly or scurry away quickly. They have large clutches of up to 20 eggs, but species' populations tend to fluctuate greatly.



**Far and wide** Gamebirds live in a variety of climatic zones and, depending on the species, prefer either forests, scrub, open habitats, or grasslands. Some types of gamebirds are much more widespread than others: for example, the quails and partriges are found on several continents across the world, whereas turkeys occur only in North America.

## FACT FILE

**Australian brush-turkey** This bird incubates its eggs by placing them in a mound of heat-generating decaying matter, adding or removing material to keep the mound's temperature constant

Up to 27 in (70 cm)
15–27
Sexes alike
Sedentary
Locally common

E. Australia

**Great curassow** This slender, forest-dwelling bird spends much of its time on the ground, foraging for fallen fruit and seeds that it picks up with its sturdy bill. It roosts and seeks refuge in trees, and also builds nests of plant matter among the branches

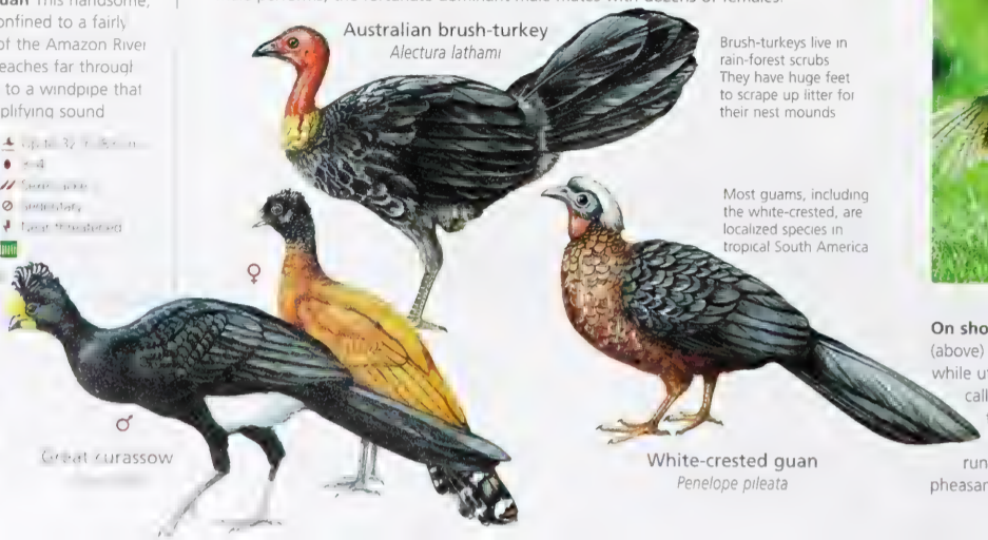
Up to 36 in (92 cm)
2
Sexes differ
Sedentary
Locally common

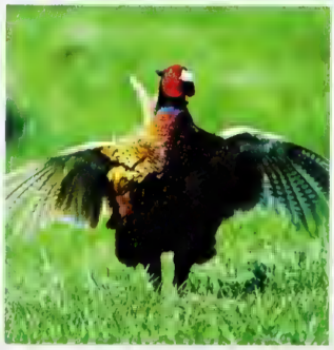
E. Mexico to far N.W. South America; Cozumel I.

**White-crested guan** This handsome, secretive bird is confined to a fairly small area south of the Amazon River. It has a call that reaches far through the forest, thanks to a windpipe that is adapted for amplifying sound

[illegible]

**Check me out** Many gamebirds stage elaborate courtship displays. Sage grouse males (*Centrocercus urophasianus*) (above) gather at strutting grounds known as leks. After each male performs, the fortunate dominant male mates with dozens of females.



**On show** A male common pheasant (above) displays by rapidly beating its wings while uttering its characteristic "crowing" call. Some species dwell primarily in trees, but most gamebirds spend much time on the ground and can run well on their strong legs. All male pheasants are brilliantly colored

**California quail**
*Callipepla californica*

California quails are popular cage-birds worldwide

**Harlequin quail**
*Coturnix delegorguei*

**Painted bush-quail**
*Perdicula erythrorhyncha*

Most bush-quails have striped faces

**Red spurfowl**
*Galloperdix spadicea*

Males have two elongated spurs on the back legs

**Red-legged partridge**
*Alectoris rufa*

Partridges are Eurasian; all have barred plumage on the sides of the body

**Red-necked francolin**
*Francolinus afer*

**Chestnut-naped francolin**
*Francolinus castaneicollis*

This species is found only in Ethiopia and Somalia, in northeast Africa

**Double-spurred francolin**
*Francolinus bicalcaratus*

This boldly striped francolin inhabits underbrush in tropical west Africa

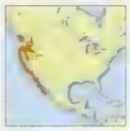
Francolins are large, stout, quail-like birds that forage in underbrush for seeds, bulbs, and insects. The gray-striped francolin is confined to west Angola, in Africa

**Gray-striped francolin**
*Francolinus griseostriatus*

**Black francolin**
*Francolinus francolinus*

## FACT FILE

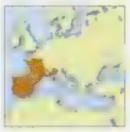
**California quail** Both sexes of this species have a head plume. Although normally herbivorous, this bird may eat various invertebrates. The young develop feathers quickly and can fly within weeks



Up to 11 in (28 cm)
13–17
Sexes differ
Sedentary
Common

W. USA, N.W. Mexico, S.W. Canada

**Red-legged partridge** The female can lay two clutches in two different nests, leaving one clutch for the male to incubate. This species has been introduced to Britain as a gamebird.



Up to 15 in (38 cm)
11–13
Sexes alike
Sedentary
Locally common

Iberia & France to N. Italy

**Double-spurred francolin** Often seen in small parties, this bird lives along the edges of wooded areas in coastal lowlands. It is usually shy and difficult to see, but sometimes calls while perching on a mound or post.

Up to 13 in (34 cm)
5–7
Sexes alike
Sedentary
Locally common

W. Morocco & S. Senegal to S. Chad & Cameroon

**Black francolin** The six subspecies of this bird differ slightly in size and plumage hue; these differences are most apparent in the females. Black francolins have been introduced in many countries.

Up to 14 in (36 cm)
6–12
Sexes differ
Sedentary
Locally common

Middle East & trans-Caucasia to N. India

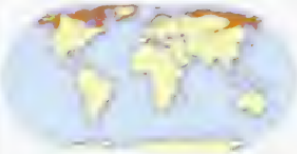
## CONSERVATION WATCH

**Under threat** Gamebirds and waterfowl are the most widely and heavily hunted birds. Because they rear large broods, they can [illegible] withstand such pressure, but when habitat destruction is added, [illegible] declines follow. The [illegible] game-birds are those with [illegible] distributions, such as the white-winged guan of northwest Peru.

## FACT FILE

**Black grouse**

**Rock ptarmigan**



**Red junglefowl** This colorful bird was

## SPURRED ON

Blue eared-pheasant
*Crossoptilon auritum*

White eared-pheasant
*Crossoptilon crossoptilon*

Red junglefowl

Koklass pheasant
*Pucrasia macrolopha*

Eurasian black grouse

Rock ptarmigan
*Lagopus muta*

Ocellated turkey

Vulturine guineafowl

Helmeted guineafowl

Mikado pheasant

Reeves' pheasant

Indian peafowl

Great argus

♂

♀

## FACT FILE

**Reeves's pheasant**

**Helmeted guineafowl**

**Great argus**

## FLIGHT MUSCLES

# WATERFOWL

| | |
|---|---|
| CLASS | AVES |
| ORDERS | 1 |
| FAMILIES | 3 |
| GENERA | 52 |
| SPECIES | 160 |

Among the first birds to be domesticated, ducks and geese were raised for food more than 4,500 years ago. Swans have also been kept in captivity, because of their beauty and grace. Several species are flightless, but the rest are powerful fliers; many northern species migrate in family groups over great distances. In the air, they flap their wings continuously and can attain maximum speeds greater than 68 miles per hour (122 km/h). Some have been observed flying at an altitude of 28,000 feet (8,485 m), near the summit of Mount Everest. Some dose on water; others come ashore to rest. Their calls range from quacks to barks, hisses, whistles and even trumpeting sounds.

**Citizens of the world** Waterfowl predominate in the Northern Hemisphere (with the largest number of species being in North America), but they can be found worldwide, except in Antarctica. They occur in almost every type of wetland, from city ponds to Arctic sea inlets. Some species spend a great deal of time at sea.

## AT HOME ON THE WATER

All species are remarkably similar in form, with short legs, webbed feet, relatively long necks, and flattened, broad bills. Most are excellent swimmers, although several species have adapted to life on land and have less webbing on their feet.

To protect them from the cold water, these birds rely on their dense, waterproof feathers and a thick coat of insulating down. Their plumage is often brightly colored and patterned.

Domestic waterfowl breeds are descended from mallards, muscovies, graylags and swan geese. Mallards, native to the Northern Hemisphere, have been widely introduced in other parts of the world, which has led to unwanted hybridization and genetic dilution of local species.

Many waterfowl consume grass, seeds, grain, and other vegetation, but some species eat fishes, insects, mollusks, and crustaceans.

The South American screamers bear little superficial resemblance to other waterfowl, but they all share certain anatomical similarities.

**Primed for take-off** [illegible]

**Know the leader** [illegible]

**Southern screamer**
*Chauna torquata*

Vulturine bill is adapted for grasping and pulling

The three species of screamers all live in tropical and subtropical South America. They feed on succulent vegetation on stream sides

**Magpie goose**
*Anseranas semipalmata*

Magpie geese are found only in the swamps of northern Australia and New Guinea. They breed in huge colonies on floating vegetation

Although its feet are only part-webbed, this bird is a good swimmer

**Snow goose**
*Anser caerulescens*

Snow geese are migratory, breeding in the north American tundra and wintering on the east and west coasts of the United States

**White-faced whistling-duck**
*Dendrocygna viduata*

This species has an unusual distribution, with widespread populations in both Africa and South America

**Red-breasted goose**
*Branta ruficollis*

**Canada goose**
*Branta canadensis*

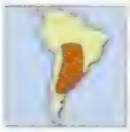
The only goose with a black head and neck ornamented with a white bib

**Bean goose**
*Anser fabalis*

Bean geese breed in the high arctic coast of Eurasia and fly south to winter in China and the Mediterranean

## FACT FILE

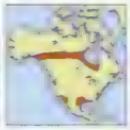
**Southern screamer** This bird lives in marshlands and along watercourses. It typically lives in groups and is a fine swimmer, despite the lack of webbing on its feet. Some indigenous people raise domesticated southern screamers.



Up to 37 in (95 cm)
3–5
Sexes alike
Sedentary
Locally common

C. & E. South America

**Snow goose** This bird has two color forms, one all white with black wing feathers, the other white-headed with a blue-gray body and wings. It breeds in the Arctic tundra and can be heard cackling as it flies.

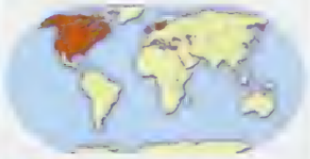


Up to 33 in (80 cm)
4–5 usually
Sexes alike
Migrant
Common

Arctic & S. North America

**Canada goose** There are about a dozen races of Canada goose, which vary in size, color, and geographic distribution. Originally native to North America, where it is a common sight in city parks, the Canada goose has been introduced widely around the world.

Up to 3½ ft (1.15 m)
4–7 usually
Sexes alike
Migrant
Common



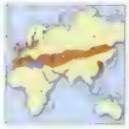
North America, N. Europe, N.E. Asia

## V-FORMATION

Canada geese are among the species of geese that migrate flying in wedge formation. The leader breaks the air and causes a streamlining effect, stirring up upwards drag field. The birds behind it conserve energy by reducing their air resistance. The birds take turns flying in the lead, and no sooner they fly as both day and night to reach summer or winter quarters.

## FACT FILE

**Common shelduck** This pugnacious bird looks heavy in flight and beats its wings slowly. It often breeds in old rabbit burrows or in gaps under old buildings. The male shelduck whistles and the female growls.

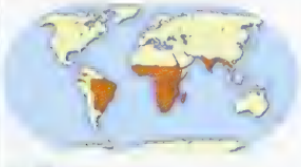


- Up to 25 in (65 cm)
- 8–10
- Sexes differ
- Migrant
- Common

W. Europe, C. Asia, N.W. Africa

**Comb duck** This bird is also known as the knob-billed duck, due to the prominent fatty comb atop the drake's bill. This comb enlarges considerably prior to the breeding season.

- Up to 30 in (76 cm) (female)
- 6–20
- Sexes differ
- Mainly sedentary
- Locally common



Sub-Saharan Africa, S. Asia, N. & E. South America

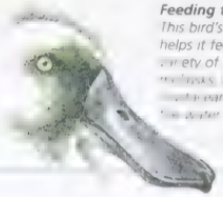
**Wood duck** This handsome duck nests in tree cavities. Nestboxes have helped to reestablish this threatened species. After nesting, the male morphs into drab, female-like plumage, but retains a distinctive red bill. The wood duck makes a nasal squealing sound.

- Up to 20 in (51 cm)
- 9–15
- Sexes differ
- Partial migrant
- Locally common

C. & S. North America & W. Cuba

## SPATULATE BEAK

The northern shoveler gets its name from its distinctive, heavy, shovel-like bill, which is longer than its head. It feeds in shallow water, extending its neck and dabbling its bill just below the water surface. Comb-like serrations along the sides of the bill help it strain food items from the water.



***Feeding tool*** *This bird's long bill helps it feed on a variety of plants, molluscs, and invertebrates in the water.*

Red-crested pochard
*Netta rufina*

Oldsquaw
(long-tailed duck)
*Clangula hyemalis*

Despite their distinctively long tails, oldsquaws dive almost exclusively for their food of crustaceans and mollusks in the Arctic

Common pochard
*Aythya ferina*

Pochards feed mostly by diving and dabbling. They paddle to the floors of lakes and swamps for mainly vegetable matter and seeds

Common mergansers dive for their food of fishes and aquatic invertebrates

Common merganser
*Mergus merganser*

Musk duck
*Biziura lobata*

This southern Australian species has a large lobe of skin under the bill

Eiders are marine, living in often rough seas around rocky coasts, and diving for mollusks and crustaceans

Common eider
*Somateria mollissima*

♀

♂

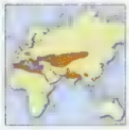
White-headed duck
*Oxyura leucocephala*

Males have an eclipse plumage, but are never as dull as the brown females

Male in full breeding plumage

## FACT FILE

**Red-crested pochard** This diving duck feeds mainly at night. To fly, it has to run over the surface of the water before it can gain enough momentum to lift itself into the air. The male may bring food or twigs to the female as part of its courtship feeding ritual

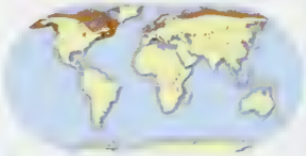


Up to 23 in (58 cm)
6–14
Sexes differ
Partial migrant
Locally common

C. & S. Europe to S. Asia, N. Africa

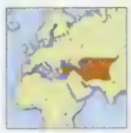
**Common eider** The down of the eider is thick and heavy, and has the best thermal insulating properties of any natural material. From a young age, the eider spends much of its time at sea, often in rough water. This bird often nests in tern colonies.

Up to 27 in (69 cm)
3–6
Sexes differ
Partial migrant
Common



N. & arctic North America, N. Europe & N. Asia

**White-headed duck** This rare duck breeds in shallow, brackish wetlands with abundant vegetation and reeds. It has declined due to hunting, habitat loss, and hybridization. The male's bright blue, swollen bill becomes smaller and grayer in winter.

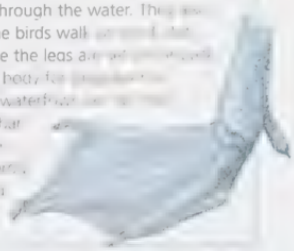


Up to 18 in (46 cm)
5–8
Sexes differ
Partial migrant
Endangered

S. Europe, Middle East, C. Asia to N. India

## WEBBED PROPELLERS

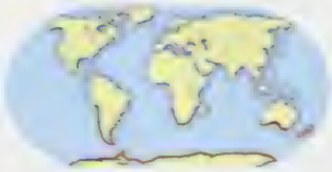
Most waterfowl are excellent swimmers, due to their webbed front toes, which act as paddles to propel them through the water. They [illegible] help the birds walk [illegible] because the legs a[illegible] on the body [illegible] water. [illegible] more [illegible] waddle [illegible] on land.



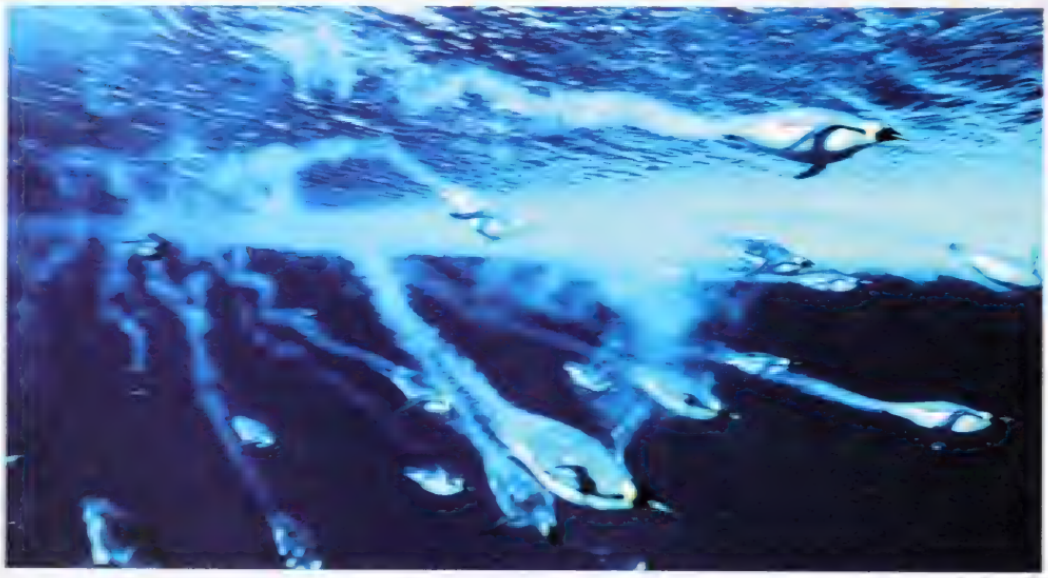
# PENGUINS

CLASS: [illegible]
ORDER: [illegible]
FAMILIES: [illegible]
GENERA: [illegible]
SPECIES: [illegible]

The most aquatic of all birds, penguins have remained unchanged in form for at least 45 million years. Although they evolved from flying birds, none of the 17 species of penguins can fly. Very highly specialized, social seabirds, they make advantage of their streamlined bodies (which minimize drag) and small flipper-like wings to travel underwater at speeds of up to 15 miles per hour (24 km/h). They spend up to three-quarters of their life in the sea, staying underwater for as long as 20 minutes or more at a time, and coming ashore only to breed and molt. Penguins eat fish, krill, and other invertebrates.



**South seas dwellers** Penguins are widely distributed throughout the colder waters of the world's southern oceans. The greatest diversity of species occurs in and around New Zealand and the Falkland Islands. The northernmost penguin lives almost exactly on the equator, at the Galápagos Islands.



**Flying through the water** Penguins are ungainly on land but underwater they are efficient swimmers (left). They often enjoy the sport of tobogganing down ice slopes on their stomachs and plunging in.

## GOING TO EXTREMES

Penguins endure a remarkably wide range of temperatures, from -80°F (-62°C) in the southern polar regions to 100°F (37°C) in the tropics. Their dense, fur-like feathers protect them by trapping warm air in an insulating layer. Penguins also benefit from a layer of blubbery fat that provides warmth as well as neutral buoyancy.

Chicks are born with insulating down, but cannot enter the water until they have grown their first adult layer of waterproof feathers. As adults, they then lose this layer when they molt and must remain ashore for 3 to 4 weeks to regrow it. During this period, they may lose a third or more of their body weight.

Penguins are superb swimmers and divers, propelling themselves with their wings, which have evolved into stiff, flat, paddle-like flippers. They twist their flippers in such a way as to provide thrust on both the upstroke and downstroke. These birds also have numerous special physiological features that allow them to regulate their body temperatures and oxygen levels in cold water.

**Brave care** Emperor penguin mates will share in chick care. In warmer, gale conditions, parents can keep their young on the ground in a dormant state, enabling penguins to endure temperatures as low as -50°F (-45°C). The mother lays her egg on the feet of her mate, who then covers it with a fold of skin. The chick hatches after about 65 days.

**A crowded life** Penguins live their young in massive colonies. A Gentoo adult lays eggs on nests of stones, and among a dense mass of other birds, which are covered in excrement. The young are fed and kept warm before growing more colorful adult feathers. The species recognized here is Gentoo (Pygoscelis papua).

### CONSERVATION WATCH

**Out of danger?** Massive exploitation for their fat and eggs decimated many species of penguins in the past, mining of guano also disturbed nesting. Such activities have slowed in recent times and, except for possibly two species, no penguins are threatened globally today.

Emperor penguin
*Aptenodytes forsteri*

Jackass penguin
*Spheniscus demersus*

King penguin
*Aptenodytes patagonicus*

Adelie penguin
*Pygoscelis adeliae*

Snares penguin
*Eudyptes robustus*

Little penguin
*Eudyptula minor*

Royal penguin
*Eudyptes schlegeli*

Yellow-eyed penguin
*Megadyptes antipodes*

## FACT FILE

**Emperor penguin** The largest penguin, the emperor is unusual in that it breeds in Antarctic winter. These penguins rarely, if ever, do dive for food, instead using their feet to keep them off the scorching ice while foraging on fish in open water.

Seen it once in December

**King penguin** The second largest penguin, and more gaudy looking than the same in large proportions, the king. They are gregarious and noisy birds. Breeding colonies can number 100,000 pairs.

Can move in two directions

**Little penguin** It could take up to 30 of the world's smallest penguin species to equal the weight of one emperor penguin. They have indigo blue and blue grey feathers (hence the common name) and, unlike most other penguins, they are crepuscular. Their calls include a wide range of sounds, from trumpeting to growling.

Lives only in Australia & New Zealand

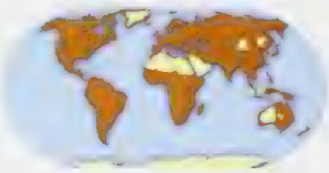
## GENTOO PENGUIN

These penguins, whose name comes from the Faroese word meaning 'fat', have red-orange bills and eyes and white patches. They build large nests using pebbles and mollet seaweed for foundation or vegetation for the breeding season. They are the only species in the genus Pygoscelis that have flippers to propel them underwater, enabling them

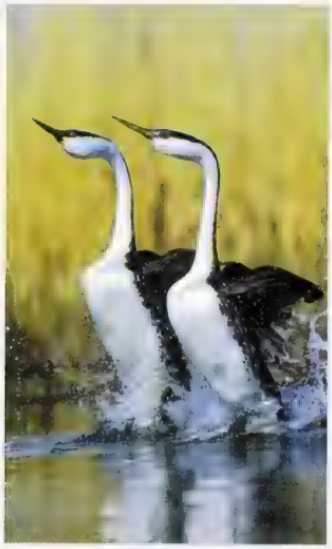
# DIVERS AND GREBES

| | |
|---|---|
| CLASS | Aves |
| ORDERS | 2 |
| FAMILIES | 2 |
| GENERA | 7 |
| SPECIES | 27 |

Although both are aquatic birds that use their webbed feet for propulsion underwater, divers (known as loons in North America) and grebes are only distantly related to each other. Their similarities are believed to be the result of convergent evolutionary paths, over the course of which they both developed features suited to diving for fishes and aquatic invertebrates. Physically, loons resemble stout ducks and cormorants that ride low in the water and have pointed bills. They are thought to be descended from wing-propelled swimming ancestors and therefore may be related to penguins and petrels. Some grebes are slim and elegant; smaller ones resemble ducklings.



**Watery world** Loons and grebes spend most of their lives on water, coming ashore only to nest (grebes even nest on the water, on floating platforms of vegetation). Loons live on freshwater lakes; grebes inhabit wetlands in general



**Dancing duo** The courtship rituals of the Western grebes (above) are very highly ritualized. They initially perform a "weed dance," holding strands of vegetation in their bills. Then they rise and run across the water surface together. Rival males also dance to defend their territories

**Feathers aren't just for flying** Great crested grebes (above) and several other grebe species eat feathers in large quantities. These form soft balls in their stomachs, perhaps protecting the birds from ingested fish bones. Because they swim much more than they fly, grebes can molt all their wing feathers at the same time.

## SKILLED SWIMMERS

Loons are shy birds that cannot walk properly. They nest on the edges of lakes, to make it easier to slip into the water, where they can swim rapidly and dive to depths of more than 200 feet (61 m) chasing fishes. They spend their winters at sea.

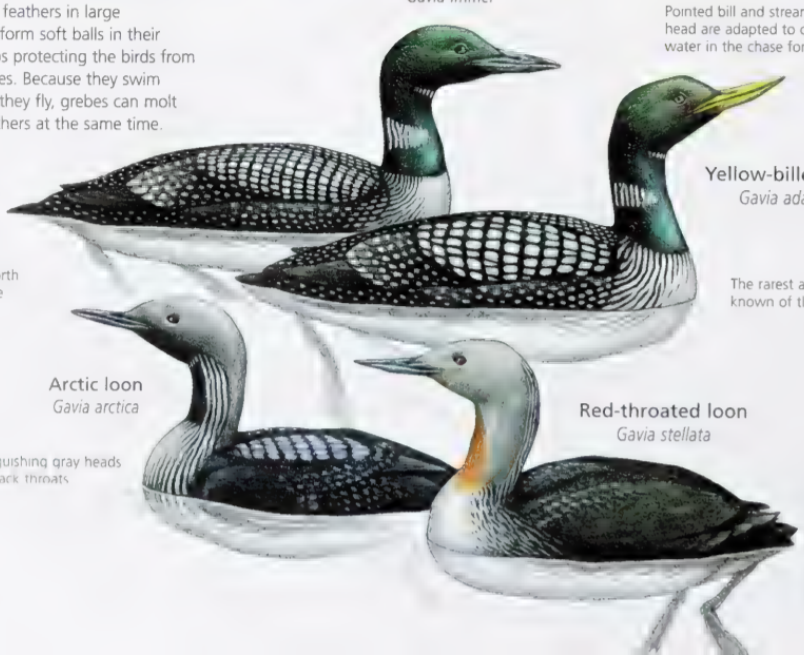
Grebes can also be elusive. They appear to lack tails; their bodies end in a powder-puff effect of loose feathers. Females often mount males during the breeding season.

Loon and grebe chicks can swim and dive as soon as they are born, but because they are sensitive to cold water, they prefer to hitch rides on their parents' backs or shelter under their parents' wings.

These birds do not fly much on a daily basis and usually avoid danger by diving underwater.

## LOON CALL

A loon (above) gives an aggressive territorial call. The loud, yodelling calls—audible for a mile (1.6 km) or more—of returning migratory [illegible] are a familiar sign of summer [illegible] North American and [illegible] These shy birds are most [illegible] migrations.




The common loon breeds in northern North America and migrates to spend winter in middle North America and Europe

Distinguishing gray heads and black throats

White-tufted grebes feed mainly on the surface of the water on fishes and aquatic invertebrates

**White-tufted grebe**
*Rollandia rolland*

**New Zealand grebe**
*Poliocephalus rufopectus*

One of two large species of grebes in North America

**Western grebe**
*Aechmophorus occidentalis*

**Great grebe**
*Podiceps major*

Named for its mostly black head

**Hooded grebe**
*Podiceps gallardoi*

**Great crested grebe**
*Podiceps cristatus*

Face plumes, called tippets, are flared in sexual display. Like other grebes, this species builds a rough nest of vegetable matter floating in water

**Eared grebe**
*Podiceps nigricollis*

**Horned grebe**
*Podiceps auritus*

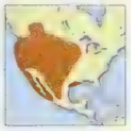
**Little grebe**
*Tachybaptus ruficollis*

If forced to leave the nest, this grebe first covers its eggs with wisps of vegetation to hide them

Lobed toes on feet placed far back on the body are much better adapted for swimming than walking

## FACT FILE

**Western grebe** This elegant bird is famous for its spectacular courtship displays. It nests in colonies on lakes and migrates to the coast. A nocturnal feeder, it belongs to the only group of grebes that spear fish with the bill

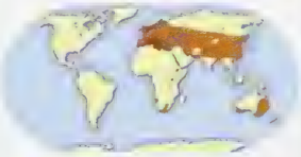


Up to 30 in (76 cm)
3–4
Sexes alike
Migrant
Locally common

W. & C. North America

**Great crested grebe** This elegant waterbird, the best-known grebe, was almost hunted to extinction in some countries for its ornate head feathers.

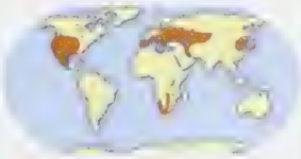
Up to 25 in (64 cm)
3–5
Sexes alike
Partial migrant
Locally common



Eurasia, S. Africa, S. Australia, New Zealand

**Eared grebe** This grebe inhabits mostly marshes, ponds, and lakes. Its feathers were once popular adornments for clothing, and its eggs were collected for food. Like all grebes, pairs perform ritual courtship and bonding dances.

Up to 13 in (33 cm)
3–5
Sexes alike
Migrant
Common



North America, Europe, Asia, Africa

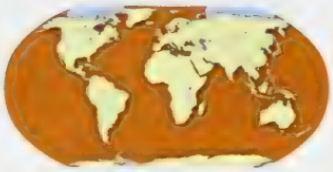
**Little grebe** This small, dumpy bird appears to have a fluffy rear end. If disturbed, it quickly submerges, reappearing some distance away. It makes loud, distinctive whinnying trills

[illegible]

# ALBATROSSES AND PETRELS

CLASS Aves
ORDERS 1
FAMILIES 4
GENERA 26
SPECIES 112

These seabirds, collectively known as tubenoses, are highly adapted to life at sea. They can glide for hours without beating their wings, and it is not uncommon for them to fly hundreds of miles (km) in search of squid, fishes, and the large zooplankton that comprise their diets. They seldom come within sight of land, except to breed. The biggest tubenose is the wandering albatross, which has the largest wingspan—up to 11 feet (3.3 m)—of any bird. Giant petrels are the size of some albatrosses, but the smallest storm petrels have an average wingspan of only about 12 inches (30 cm). Diving petrels have small, rigid wings as much suited for underwater propulsion as for flying.



**Ocean-going birds** Albatrosses are most frequently associated with the windswept expanses of southern oceans

**Nesting instinct** Two Laysan albatross (*Diomedea immutabilis*) parents tend their week-old chick (above). Adults regurgitate a fattening mixture of half-digested food and stored oil to feed their young, which take up to 9 months to fledge

**Greeting display** Wandering albatrosses (*D. exulans*) (left) greet each other with outstretched wings. Up to eight males may take part in courtship ceremonies

## EXPRESSING THEMSELVES

Tubenoses are found throughout the world's oceans. They have large, external, tubular nostrils and a relatively well-developed sense of smell that they may use to locate food, breeding sites, and each other. All species have a musty body odor that persists for decades in museum exhibits.

Most tubenoses store large quantities of oil in their stomachs, which they regurgitate for their young or eject to deter predators.

The male and female perform spectacular courtship displays on the ground, facing each other with their wings spread and their tails fanned, throwing their heads back as they gurgle and bray. They renew their bonds with their life partners with complex head movements and rituals that can last for days.

Tubenoses are long-lived birds, but do not begin breeding until they are at least 10 years old. Some only breed every other year.

### CONSERVATION WATCH

Albatrosses and other large tubenoses are seriously threatened by long-line fishing. The birds follow fishing ships, dive for bait on lines thrown overboard, get hooked, and drown. Another albatross, the short-tailed albatross (*Phoebastria albatrus*), was hunted almost to extinction for the feather trade in the early 20th century. The 78 species of Procellariiformes on the IUCN Red List are categorized as follows:

| | |
|---|---|
| 3 | Extinct |
| 13 | Critically endangered |
| 14 | Endangered |
| 31 | Vulnerable |
| 13 | Near threatened |
| 4 | Data deficient |

Gray petrel
*Procellaria cinerea*

Fiji petrel
*Pseudobulweria macgillivrayi*

A rare species known only from around Fiji

Jouanin's petrel
*Bulweria fallax*

Bulwer's petrel
*Bulweria bulwerii*

Manx shearwater
*Puffinus puffinus*

Longer, more pointed wings, forked tails, and short feet distinguish northern storm-petrels from those in Southern Hemisphere waters

Band-rumped storm-petrel
*Oceanodroma castro*

Diving-petrels have small, chunky, bullet-shaped bodies adapted to plunge-diving for food

Common diving-petrel
*Pelecanoides urinatrix*

This transequatorial migrant is the most widespread storm-petrel in the world

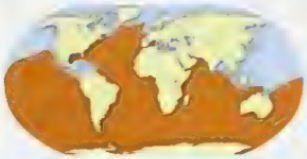
Wedge-tailed shearwater
*Puffinus pacificus*

Wilson's storm-petrel
*Oceanites oceanicus*

## FACT FILE

**Wilson's storm-petrel** Like other storm-petrels, this bird is colonial and nests in rock crevices or underground, mostly on isolated islands. It makes long migrations, traveling between the Antarctic and the subarctic.

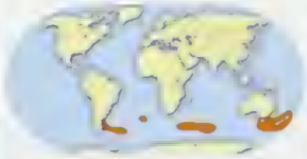
- Up to 7½ in (19 cm)
- 1
- Sexes alike
- Migrant
- Common



Antarctica, all oceans to north of equator

**Common diving petrel** This bird dives for its food, traveling through water and air with equal ease. Its tubular nostrils open upward rather than forward to prevent water entering.

- Up to 10 in (25 cm)
- 1
- Sexes alike
- Sedentary to locally nomadic
- Common



Southern Ocean of S.E. Australia & New Zealand, S.W. Africa & S.W. South America

## THE LONG WAY HOME

Several shearwaters are examples of birds that migrate in a loop pattern. They skirt the coastline of one continent in the spring and a different one in the fall, in a large figure-eight pattern. Loop migration may be undertaken due to food availability, ocean currents, prevailing winds, and temperature.

# MIGRATIONS

**Travelers** Garden warblers (*Sylvia borin*) (above) spend their summers in Europe and their winters in Africa.

**Epic journey** The arctic tern (*Sterna paradisaea*) (below) migrates over a greater distance than any other bird species. Twice a year, these birds fly between the two polar regions.

Nearly half of the world's birds divide their time between two main localities. Most migrate because of seasonal fluctuations in the availability of food. Many species travel alone, but others prefer to migrate in flocks comprising one or more species. They travel either by day or night, and either overland or across oceans. Most break the journey into short hops of a couple of hundred miles (km). But terrestrial birds that cross oceans and cannot land on water must complete the entire journey in one epic flight. One such bird is the American golden plover, which flies between Alaska and Hawaii, a journey it undertakes twice a year. To prepare for such energy-intensive journeys, birds load up on food almost equal to their regular weight before they leave.

**Look up** Loud flocks of migrating snow geese (*Chen caerulescens*) (above) are a breathtaking sight in parts of North America.

## SUN AND MIGRATION

Environmental cues such as day lengths and temperatures tell birds when it is time to migrate. They also navigate by other cues, including landmarks, the position of the sun and stars, and the Earth's magnetic field. Birds have a keen time sense as well that helps them judge journey lengths.

A bird innately knows it should fly at a certain angle to the sun.

In a cage where mirrors deflect the sun's angle, the bird reorients.

No matter how the sun's angle is altered, the bird flies relative to it.

# FLAMINGOS

| | |
|---|---|
| CLASS | Aves |
| ORDERS | 1 |
| FAMILIES | 1 |
| GENERA | 3 |
| SPECIES | 5 |

These distinctively beautiful birds are easily recognized by their bright pink or red and white plumage, their long legs and neck (proportionately longer than on any other bird), and their oddly depressed bills. There are five species of flamingo; the largest is the greater flamingo, which reaches a height of nearly 5 feet (1.5 m). Vast flamingo flocks that congregate on the lakes of the Great Rift Valley are one of the famous natural spectacles of Africa. The reddish color of flamingo plumage comes from carotenoid proteins in the birds' diet of plant and animal microplankton. Liver enzymes break down these proteins into usable pigments that are deposited in both skin and feathers.

**Old salts** Flamingos were once found on every continent, but have disappeared from Australasia. These mainly tropical birds live in shallow lakes and coastal regions, preferring salty or brackish water They inhabit some isolated islands and can also be seen at high altitudes in the Andes

**All together now** Greater flamingos (right) are gregarious birds that build conical nests out of mud and sand that they scrape together in shallow waters in Central Africa and the Caribbean.

***Unusual angle***
*The long neck and downturned bill are adapted to feeding by immersing the head deep under water for long periods.*

## SPECIALIZED FEEDERS

The evolutionary lineage of flamingos is still something of a mystery, though they may represent the link between herons and their allies, and waterfowl.

The flamingo's strongly hooked bill is well designed for filter feeding on small shellfish, insects, single-celled animals, and algae. To feed, the bird bends forward, turns its head upside down (looking backward between its legs) and drags its opened bill through the water. After closing its bill, it uses its lower jaw and tongue (which has tooth-like projections) to pump water and mud out through the slits lining the upper jaw. The bird then swallows the food that remains.

The shallow waters where flamingos live sometimes drain away, forcing them to travel great distances to more abundant feeding grounds. The flocks travel at night, honking as they fly.

Flamingos nest on lakes and in coastal regions, laying one or two eggs per breeding season. The young can run and swim well at an early age, leaving the nest to follow their parents around by the time they are about 4 days old, and flying by the age of 70–80 days.

Adults sometimes swim rather than walk while they feed in deep waters, often at night.

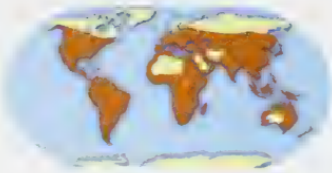
### CONSERVATION WATCH

**Salty habitats** As flamingos live in saline waters, their wetland habitats have not been as affected as those of other water birds. Even so, two species found only in the South American Andes, the Andean flamingo and Puna flamingo (*Phoenicoparrus jamesi*), are considered threatened.

# HERONS AND ALLIES

CLASS Birds
ORDERS 2
FAMILIES 5
GENERA 41
SPECIES 116

This group of long-legged wading birds includes herons, storks, ibises, and spoonbills. They can step through water without getting their plumage wet as they search for fishes, insects, and amphibians to eat. Some types of herons are known as egrets; they were thus named for their special, filamentous breeding plumage, which was highly sought after by 19th-century hat-makers. Many species within this group are gregarious, and large groups comprising several species can sometimes be seen feeding, roosting, or nesting together. The white stork, a migratory bird that often nests in pairs on chimneys, has long been associated with human births in folk tales.



**Freshwater dwellers** Herons and their allies live worldwide, except near the poles. They are typically found in or near various types of freshwater habitats, including swamps, marshes, rivers, streams, lakes, and ponds However, several species have adapted to drier environments.

**A safe perch** Although they spend most of their waking time above the ground, some birds, including scarlet ibises, have been seen in large groups roosting on low branches in trees or on the ground.

**A catch** A young great blue heron (above right) holds a fish it has just caught. Most herons have long bills with which to stab at fishes. The bills of other birds in this group vary, depending on their diets and feeding styles.

## WADING IN

All birds in this group have short tails and long beaks and necks, as well as long legs. Nonetheless, there is considerable variation in size, color, plumage pattern, and feeding behavior among species.

Some species have specialized to fill very specific niches. The cattle egret, for example, follows grazing animals such as buffalo, eating the insects disturbed. Some herons camouflage themselves in marshes; if approached, they try to blend in with the reeds by pointing their heads skyward, compressing their bodies, and swaying with the vegetation. Unlike their close relatives, herons fly with their heads folded back on their shoulders, making them easy to recognize.

Like some other types of birds, herons have specialized patches of feathers called powder-down. These are never molted, but grow continually. As the tips fray, they turn into a fine powder, which the bird picks up in its bill and uses to remove slime and oil from its feathers when grooming. Some storks and ibises have bare necks, perhaps to prevent fouling plumage while eating carrion. Most species in this group migrate long distances, maybe because their large bodies would require a great deal of energy to warm in winter.

Black-headed heron
*Ardea melanocephala*

Gray heron
*Ardea cinerea*

Whistling heron
*Syrigma sibilatrix*

Long, articulated neck for stabbing strikes at prey

Long, bare legs and feet for wading

Great blue heron
*Ardea herodias*

Goliath heron
*Ardea goliath*

Purple heron
*Ardea purpurea*

Cattle egret
*Bubulcus ibis*

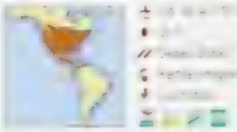
Capped heron
*Pilherodius pileatus*

Chinese egret
*Egretta eulophotes*

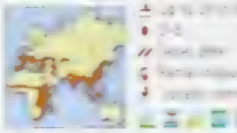
## FACT FILE

**Gray heron** This colonial bird generally nests high up in trees, often with other species. Both parents duck into the nest to feed the young, which remain in the nest for almost 2 months. The gray heron's diet sometimes includes small birds.

**Great blue heron** This bird has both white and gray shades in different regions. The most familiar large wading bird in North America, it prefers deep stalking the larger fish, amphibians, or mammals.



**Purple heron** Less colorful than the larger gray heron, the purple heron nests along or in colonies among reeds. A common bird, it sometimes eats small birds, and small mammals in addition to its staple diet of amphibians, fishes, and invertebrates.



## SHADOW HUNTING

## FACT FILE

**Hamerkop** Named for its hammer-shaped head, the hamerkop generally lives alone or in pairs. It flies in a slow, undulating way and has a raucous call. It feeds on aquatic animals, primarily at twilight or at night

Up to 22 in (56 cm)
3–6
Sexes alike
Sedentary
Locally common

Sub-Saharan Africa, Madagascar

**Shoebill** This rather odd-looking bird is thus named because it appears to be wearing a clog on its face. Its large bill, which it usually rests on its breast, is well adapted for catching the slippery lungfish found in its wetland habitats.

Up to 4 ft (1.2 m)
1–3
Sexes alike
Sedentary
Near threatened

C. Africa

**Sacred ibis** This distinctive bird was very prominent in ancient Egyptian mythology, symbolizing Thoth, the god of writing and wisdom. The Egyptians mummified these birds. Sacred ibis eventually became extinct in Egypt, although they still thrive elsewhere.

Up to 35 in (90 cm)
2–3
Sexes alike
Partial migrant
Common

Sub-Saharan Africa & W. Madagascar

**Madagascan crested ibis** This large terrestrial bird feeds on moist ground in forests and scrubs. When disturbed, it prefers to run away rather than fly, dodging through trees along the way

Up to 20 in (50 cm)
Sexes alike
2–3
Sedentary
Near threatened

E. & W. Madagascar

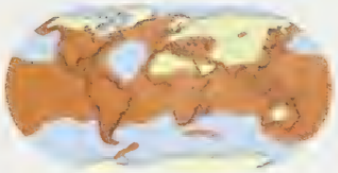
## CONSERVATION WATCH

**Waning wetlands** The draining and pollution of wetlands worldwide have caused marked contractions in the populations of many species of herons and allies that rely on these habitats for food. Several species of Asian storks, known as the Asian adjutants, have also collapsed from loss of food and poisoning.

# PELICANS AND ALLIES

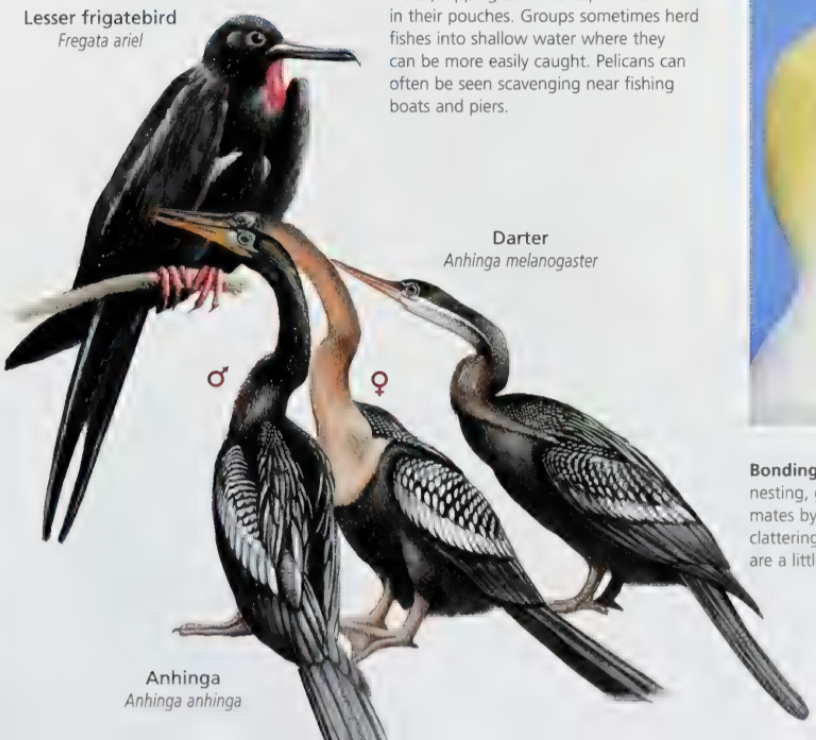
| | |
|---|---|
| CLASS | Aves |
| ORDERS | 1 |
| FAMILIES | 6 |
| GENERA | 8 |
| SPECIES | 63 |

The distinctive pelicans (which have been in existence since mid-tertiary times, up to 30 million years ago) are related to four other families of water birds: tropicbirds; gannets and boobies; cormorants and anhingas; and frigatebirds. They all have webbed feet that allow them to move easily through water, and the webbing extends uniquely across all four toes. Many have large, naked throat sacs that are used to hold fishes or as a sexual attractant in courtship displays. Unusually extensive air-sac systems in their chests and lower necks make those areas well-cushioned (hence protective in diving) and buoyant. They eat primarily fishes, as well as squid and other invertebrates.



**A varied range** Pelicans and their close relatives are found in all types of water environments, from open oceans and sea coasts to lakes, swamps, and rivers. Most species live in tropical or temperate areas

**Pelican party** Most pelicans (above) feed as they sit on the surface of the water, dipping down to capture fishes in their pouches. Groups sometimes herd fishes into shallow water where they can be more easily caught. Pelicans can often be seen scavenging near fishing boats and piers.



**Bonding** During courtship and when nesting, gannets (above) bond with their mates by "billing," rapidly and noisily clattering their bills together. Male gannets are a little larger than females

Darters and anhingas may look like cormorants, but instead of diving underwater to chase their prey, they submerge like a submarine

## EXPERT FISHERS

These birds are much better suited to water than land. Tropicbirds cannot even walk because their legs are situated too far back on their bodies, and so they have to push themselves forward on their bellies. One species of cormorant in the Galápagos Islands cannot fly. But pelicans are surprisingly graceful in the air, despite being among the largest of flying birds in terms of body weight. Frigatebirds, on the other hand, are very lightweight and can remain in the air for days.

Pelicans and their allies are skilled at catching fish. Some species dive from great heights. For centuries, Chinese fishermen have attached roped collars to cormorants, letting them out to catch (but not swallow) fishes, before pulling them back to the boats and taking their prey.

Cormorants and darters lack waterproofing in their wings. This allows them to dive deeper and in general to move through water more efficiently. But their plumage eventually becomes waterlogged, forcing them to spend considerable time ashore waiting for it to dry.

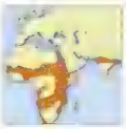
All of the group breed in large colonies with other species, but may vigorously defend their individual patches. All stages of the breeding cycle may be synchronized within a colony. Many of these birds reuse the same nest sites year after year

### CONSERVATION WATCH

**Under threat** Although many species of pelicans and their allies live at sea and nest on remote islands, they have still been vulnerable to massed killing at their breeding colonies and to disturbance from guano extraction. Two endangered species breed only on Christmas Island

## FACT FILE

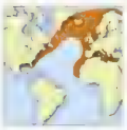
**Great white pelican** Because of its size (it is among the heaviest flying birds in the world), the great white pelican relies as much as possible on thermals. For reasons of balance, it cannot fly with a full pouch.



Up to 5¼ feet (1.75 m)
1–3
Sexes alike
Partial migrant
Locally common

S.E. Europe, Africa, S. & S.C. Asia

**Northern gannet** This bird is distinctive in flight, with its pointed tail and beak, and long, narrow wings. It nests in colonies on rocky coasts, and is renowned for its spectacular high dives in search of fish.



Up to 36 in (92 cm)
1
Sexes alike
Partial migrant
Locally common

N. Atlantic, Mediterranean Sea

**Blue-footed booby** The name booby is thought to be derived from the Spanish word for "clown." This second-rarest of boobies dives for fish, attaining such a high speed that it passes its prey and must then snatch it from below as it resurfaces.

Up to 33 in (84 cm)
1–3
Sexes alike
Partial migrant
Locally common

N.W. Mexico to N. Peru, Galápagos Is

## PRE-DIGESTED FOOD

Before pelican chicks are old enough to hunt for themselves, they stick their bills down their parents' throats, prompting them to regurgitate a half-digested fish meal. Unlike adult pelicans, which are essentially voiceless, chicks use their voices to loudly beg for food.

***Lunch box***
*The bill pouch of a pelican does more than snare fishes. It also serves as a receptacle for regurgitated food for its young.*

Double-crested cormorant
*Phalacrocorax auritus*

Adults have short crests on either side of the head and bright orange skin under the bill

Great cormorant
*Phalacrocorax carbo*

The most widespread species of cormorant

White patches develop on the flanks in breeding plumage

Kerguelen shag
*Phalacrocorax verrucosus*

Breeding adult European shags develop a short crest on the head

European shag
*Phalacrocorax aristotelis*

Pelagic cormorant
*Phalacrocorax pelagicus*

Imperial shag
*Phalacrocorax atriceps*

Tail is flattened out when bird swims and can be used as a rudder

Rough-faced shag
*Phalacrocorax carunculatus*

## FACT FILE

**Great cormorant** This cormorant, the largest, nests on rocky coasts and in trees in colonies, constructing crude mounds from plant materials. It is often seen perching with wings spread to dry.

- Up to 3¼ ft (1 m)
- 3–5
- Sexes alike
- Partial migrant
- Common

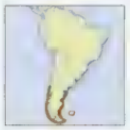
E. North America, Eurasia, C. & S. Africa, Australia

**European shag** This colonial seabird builds its nests on cliffs. It grunts and croaks during the breeding season but remains generally silent in winter.

- Up to 31 in (79 cm)
- 2–4
- Sexes alike
- Sedentary
- Locally common

Coastal Europe, Mediterranean Sea & Iceland

**Imperial shag** The sexes of this bird are similar in appearance. Imperial shags remain close to the coasts in the cold southern waters where they live. Island-based populations have remained isolated from each other and therefore exhibit slight variations.



- Up to 30 in (76 cm)
- Sexes alike
- 2–3
- Sedentary
- Locally common

Coasts of S. South America, Falkland Is

## GANNET DIVE

Gannets regularly plunge from a height of about 100 feet (30 m). Their three-dimensional vision (a result of having both eyes positioned toward the front of the head) helps them pinpoint prey

***Missiles away*** *Gannets plunge-dive head-first into a school of fishes After catching their prey, they surface to eat it or fly off with it*

# BIRDS OF PREY

CLASS Aves
ORDERS 1
FAMILIES 3
GENERA 83
SPECIES 304

These skilled hunters are collectively known as raptors, from the Latin word meaning "one who seizes and carries away." They comprise one of the avian world's largest orders, with members ranging from the world's fastest birds to its ugliest scavengers, and varying in standing height from 6 inches (15 cm) to more than 4 feet (1.2 m). The group includes eagles, kites, falcons, buzzards, vultures, and hawks. The raptors' hunting prowess has awed humans throughout history, making them common features on military insignia, national crests, and business logos. They all have large eyes and powerful beaks and claws, but there is considerable variety in behavior among the groups.

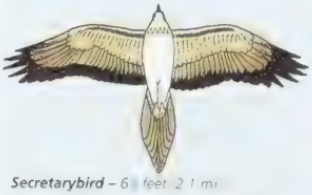
**Widespread predators** Raptors are found in most habitats, from Arctic tundra to tropical rain forests, deserts, marshes, fields, and cities. Because they need space for their hunting, their presence is determined by physical environment rather than by type of vegetation

### WINGING IT

Some raptors have long, broad wings suited for soaring while looking for carrion or live prey on the ground far below. Others have more pointed wings that allow them to fly quickly and change direction rapidly

*Andean condor* – 9 feet (2.9 m)

*Bearded vulture* – 8 feet (2.5 m)



*Secretarybird* – 6 feet (2.1 m)

*White-bellied sea eagle* – 6½ feet (2 m)

*Rough-legged buzzard* –

*Peregrine falcon* –

*Lesser kestrel* –

**Got it** Some raptors such as this osprey (above, top) specialize in swooping upon prey, which they grab and carry off with their talons. Many species can fly far and wide in search of prey. Scavengers do not need to be as agile and instead may soar for long periods or perch on trees or mounds looking for a kill.

**A meaty treat** Like this bald eagle (above), most raptors breed in trees, although some nest among vegetation on the ground or in small hollows scraped on cliff edges. There is usually a clear division of labor, with mothers being the ones who offer torn-up prey to nestlings

**Sizing up** Female raptors are typically larger than their male counterparts, as in the case of this pair of African fish eagles (*Haliaetus vocifer*) (above). This dimorphism is less pronounced among species that eat slower-moving or immobile prey

## SUPREME HUNTERS

Raptors have sharp, hooked bills adapted for tearing flesh; powerful feet and talons for grabbing prey; and large eyes for spotting their quarry in daylight. Their diets vary from species to species and include insects, birds, mammals, fishes, and reptiles. Anatomical features vary accordingly. Long toes help falcons grab airborne prey. Their sturdy legs allow them to hit birds hard enough to incapacitate them. Large legs and talons help forest eagles capture monkeys, sloths, and other large, tree-dwelling mammals.

Raptors are renowned for their keen eyesight and aerial prowess. A rabbit that a human can barely see at a distance of 1,640 feet (500 m), a wedge-tailed eagle can see from a mile (1.6 km) away. Eagles, hawks, and ospreys often swoop suddenly when they spot a likely target.

Many scavenging raptors have bare skin on their heads and necks, perhaps to prevent messing up their feathers when they stick their heads into carcasses, or else to assist with regulating body temperature.

Andean condor
*Vultur gryphus*

World's largest bird of prey

California condor
*Gymnogyps californianus*

Black vulture
*Coragyps atratus*

Like most vultures, these birds are scavengers and have weak talons

Turkey vulture
*Cathartes aura*

King vulture
*Sarcoramphus papa*

Osprey
*Pandion haliaetus*

The ultimate fish-catching raptor, the osprey ranges around the coasts of the world

Black baza
*Aviceda leuphotes*

African cuckoo-hawk
*Aviceda cuculoides*

Cuckoo-hawks are inoffensive raptors that hunt low over tree tops in search of large insect food, or dive on small reptiles from set perches

Hook-billed kite
*Chondrohierax uncinatus*

## FACT FILE

**California condor** This scavenger has the longest nestling period—5 months—of any bird. During this time, the young are totally dependent on the parents. The California condor is now being bred in captivity and released into the wild in efforts to save it

Up to 4½ ft (1.3 m)
Up to 9 ft (2.7 m)
1
Sedentary
Critically endangered

S.W. USA

**Osprey** This bird lives near lakes, rivers, and seashores. It builds huge, crude nests of dry twigs, branches, and other plant matter that it accumulates over years. It feeds almost exclusively on fishes

Up to 23 in (58 cm)
Up to 5½ ft (1.7 m)
2–4
Partial migrant
Common

N. & S. America, Eurasia, Africa, Australia

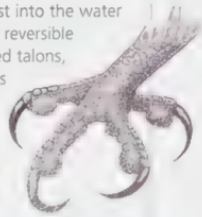
**King vulture** This distinctive bird is still quite common. It typically nests high up in trees and feeds on carrion. It uses its strong beak to tear apart and eat the flesh of carcasses ahead of its rivals

Up to 32 in (81 cm)
Up to 6½ ft (2 m)
1
Sedentary
Locally common

Central & N. & C.E. South America

## POWERFUL TOOLS

Ospreys drop feet first into the water to catch fishes. Their reversible outer toe, long curved talons, and rough, spiny toes (with thorny growths called "spicules") help them grab and carry prey. Like all raptors they have strong, curved beaks to tear flesh



## FACT FILE

**Snail kite** This raptor eats only water snails, which it collects in freshwater lowland marshes. Snail kites frequent open places, where they sometimes gather in large flocks. Nests are built among grasses and aquatic bushes.

Up to 17 in (43 cm)
Up to 3½ ft (1.1 m)
2–3
Partial migrant
Locally common

S.E. USA, C. America, N.E. South America

**Bald eagle** This bird became the national symbol of the United States due to its fierce look. It hunts mainly fishes, though it may also feed on ducks or carrion. It has also been known to steal food from other birds.

Up to 38 in (96 cm)
Up to 6½ feet (2 m)
1–3
Migrant
Locally common

North America, S. to N. Mexico

**Short-toed eagle** This eagle prefers to nest in evergreen trees. Its habitat includes terrain with scrubby vegetation and woods with large clearings. It eats mainly reptiles, especially snakes and lizards. It even eats venomous snakes.

Up to 26½ in (67 cm)
Up to 73 in (1.85 m)
1
Partial migrant
Locally common

N.W. Africa, W. to C. Eurasia, W. China & India

## PAIR BONDS

Like most raptors, bald eagles are monogamous. Pairs renew their bonds with spectacular acrobatic displays. The male usually dives toward the female, who flies below. She then rolls and raises her legs. She might then grasp his feet as the two of them tumble together.

*Flying united*

Lammergeier
*Gypaetus barbatus*

Cinereous vulture
*Aegypius monachus*

Lappet-faced vulture
*Torgos tracheliotus*

These huge vultures feed mainly on the large bones of animal carcasses, which they break open on rocks

Eurasian griffon
*Gyps fulvus*

Egyptian vulture
*Neophron percnopterus*

Hooded vulture
*Necrosyrtes monachus*

African white-backed vulture
*Gyps africanus*

Palm-nut vulture
*Gypohierax angolensis*

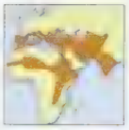
## FACT FILE

**Eurasian griffon** The largest type of vulture in Europe, this bird prefers to nest, roost, and soar in mountainous terrain, but then moves to open plains to feed. It eats carrion, mainly from large mammals such as sheep

Up to 3½ ft (1.1 m)
Up to 9 ft (2.8 m)
1
Sedentary
Locally common

N. & S. Africa, S. Europe to Middle East & Caucasia

**Egyptian vulture** This scavenger builds crude nests using small branches and rubbish, which it typically places in holes and nooks in rocks. Its diet includes rotten fruit, rubbish, carrion, and dung.



Up to 27 in (69 cm)
Up to 5½ ft (1.7 m)
2
Partial migrant
Locally common

S. Europe, N. & E. Africa, S.W. Asia to India

**Hooded vulture** This vulture cannot compete with larger scavengers at carcass sites, so it circles around the periphery, picking at scraps. It is the only member of this species group that can live in areas of high rainfall.

Up to 27 in (69 cm)
Up to 6 ft (1.8 m)
1
Sedentary
Common

Sub-Saharan Africa excl. Congo Basin

## SCAVENGING

Like other griffon vultures, Ruppell's griffons are gregarious birds. Several hundred may descend to feed on a carcass that one of them has spotted

## CONSERVATION WATCH

**Vulture populations collapse** Across southern Asia, vulture populations collapsed at the close of the 20th century. The reason was found to be poisons concentrated in carrion and other sources, which caused the vultures' kidneys to fail.

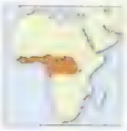
## FACT FILE

**Gabar goshawk** This bird has two very different color forms, one gray and one mostly black. It hunts birds, mammals, lizards, and insects by swiftly flying out from trees. It prefers lower rainfall areas.

Up to 14 in (36 cm)
Up to 24 in (60 cm)
2–4
Partial migrant
Common

Sub-Saharan Africa excl. Congo, S. Yemen

**Congo serpent-eagle** Very little is known about the distinctively long-tailed Congo serpent-eagle. Its large eyes help it see in the dimly lit forest understory. It eats chameleons, lizards, and other animals aside from snakes.



Up to 20 in (51 cm)
Up to 3 ft 11 in (1.1 m)
Unknown
Sedentary
Locally common

Liberia to Congo Basin

**Northern harrier** Formerly called a marsh hawk, the northern harrier is widespread in grasslands and open fields, especially in marshy areas. Unlike other hawks, it rarely perches on anything higher than a fence post.

Up to 20 in (51 cm)
Up to 4 ft (1.2 m)
3–6
Migrant
Common

North & Central America, N. & C. Eurasia

## FLEDGLINGS

Most raptors breed in trees, but northern harriers nest on the ground among tall vegetation. The female feeds the young with food brought by the male until they are ready to fly and hunt for themselves, about a month after hatching.

Lizard buzzard
*Kaupifalco monogrammicus*

Congo serpent-eagle
*Dryotriorchis spectabilis*

Gabar goshawk
*Micronisus gabar*

Crested serpent-eagle
*Spilornis cheela*

Hunts from exposed perches, diving to pounce on tree snakes and other reptiles

Dark chanting-goshawk
*Melierax metabates*

Black harrier
*Circus maurus*

Harriers hunt low over open areas and grassland gliding on upraised wings while looking for prey

Northern harrier
*Circus cyaneus*

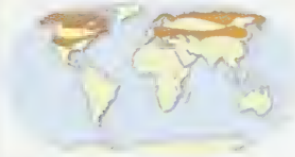
Western marsh-harrier
*Circus aeruginosus*

Harriers have long, slender feet and legs adapted for reaching into vegetation and grasping small prey, from shallow dives or drops

## FACT FILE

**Rough-legged hawk** This bird is one of the few raptors that breed in the Arctic. After raising its young above the treeline on open Arctic tundra, it migrates to its winter quarters marshes and farmlands of North America, Europe, and Asia.

- Up to 24 in (60 cm)
- Up to 5 ft (1.5 m)
- 3–5
- Migrant
- Common



North America, N. & C. Eurasia

**Eurasian sparrowhawk** This raptor lives in forested areas interspersed with open spaces. It hunts its prey by flying low along the edge of the woods, catching mostly birds, as well as small mammals and insects.

- Up to 15 in (38 cm)
- Up to 29 in (74 cm)
- 3–6
- Partial migrant
- Uncommon

Europe, far N. Africa, N. to S. Asia

## FIGHTING BIRDS

Raptors sometimes squabble over prey. Eurasian buzzards attack each other with their powerful feet and sharp talons. Beaks, no matter how dangerous looking, are never used

***Foot fighting***
*Two competing hawks try to get the upper hand the only way they know*

## FACT FILE

**Crowned hawk-eagle** This very large, powerful eagle primarily hunts mammals such as small antelopes, although it also occasionally eats reptiles, including venomous snakes. It is a noisy bird when courting.

- Up to 3¼ feet (1 m)
- Up to 6 ft (1.8 m)
- 1–2
- Sedentary
- Declining

C. to S.E. Africa

**Secretarybird** The only living representative of its family, the secretarybird has no close relatives. It is a semi-terrestrial raptor that strides over grassland plains, looking for prey it can subdue with a kick from its long legs, short, stout toes and nail-like claws. Insects and smaller reptiles form its staple diet.

- Up to 5 ft (1.5 m)
- Up to 7 ft (2.1 m)
- 1–3
- Sedentary
- Locally common

Sub-Saharan Africa excl. Congo Basin

**Golden eagle** This large bird reuses its crude nests, typically building several on rocks or in trees, and using them in turn. It hunts mammals and birds, and also eats carrion. Its defended breeding area can cover 25,000 acres (10,120 ha).

- Up to 3¼ ft (1 m)
- Up to 7 ft (2.2 m)
- 1–3
- Partial migrant
- Locally common

North America, Eurasia, N. Africa

## CONSERVATION WATCH

**Raptor watch** Raptors have declined around the world, not so much from direct habitat loss as from loss of prey due to habitat destruction. Shooting, persecution, and nesting failure due to DDT accumulation from prey have also taken their toll. IUCN lists one species as extinct—the Guadelupe caracara (*Caracara lutosus*)—14 as endangered (10 of these critically so), 27 as vulnerable, [illegible] as near threatened, and one as data deficient.

# HUNTING METHODS

Raptors hunt and kill their prey in a variety of ways, although their powerful feet and sharp talons are their main weapons. Some pursue airborne prey; others capture terrestrial reptiles and mammals. Hawks kill with their strong grips, squeezing their victims to death. Some vultures drop tortoises until they break, then swoop down to eat the flesh inside. Sea eagles and ospreys snatch fishes out of the water. The unusual secretarybirds subdue their prey by kicking it. And the African harrier-hawk has extraordinarily flexible legs which it can bend at extreme angles to grope inside tree hollows for nestling birds and other small animals.

**CRACKING UP**
Egyptian vultures sometimes use tools such as twigs to open ostrich eggs. They may also drop eggs from the air, or hurl stones at eggs that are too large to drop. Lammergeiers also drop large bones onto favored rocks ("ossuaries") to break them up for eating.

**Stages in prey capture** Falcons strike and take their prey in mid air. Here we see the sequence of attack by a peregrine falcon: circling to scout prey (top left); the attacking dive (left); the hit, a Eurasian oystercatcher (below).

**Outfoxing prey** Eagles (above) use their powerful legs and sharp talons to catch and kill mammals such as foxes. Fishes can be slippery prey, but fish eagles have particularly large talons with spiny soles to cope with this problem.

## FACT FILE

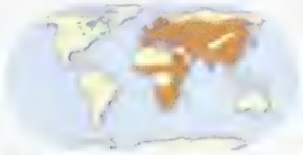
**Collared falconet** One of the smallest birds of prey, this shy and nervous bird roosts and breeds in abandoned barbet or woodpecker holes in old trees. It seldom rests for long in any one spot.

- Up to 7 in (18 cm)
- Up to 13 in (34 cm)
- 4–5
- Sedentary
- Locally common

Himalayas & N. India to Myanmar & Indochina

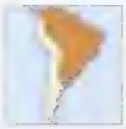
**Eurasian kestrel** This species lives in a variety of open habitats, from rocky sea coasts to mountains and cultivated fields. It sometimes builds its nests on building ledges or in the abandoned nests of other birds.

- Up to 15 in (38 cm)
- Up to 32 in (81 cm)
- 3–6
- Partial migrant
- Common



N. to S. Eurasia, sub-Saharan Africa

**Yellow-headed caracara** Outside the breeding season, this bird roosts in large colonies. In the morning, the individuals head to their respective hunting grounds. The caracara has harsh, cat-like cries. It is often attacked by other birds.



- Up to 17 in (43 cm)
- Up to 29 in (74 cm)
- 1–2
- Sedentary
- Common

Central to N. & E. South America

## ALL IN THE FAMILY

The family Falconidae includes true falcons and caracaras. Unlike true falcons, caracaras walk about on the ground, [illegible]

*Contrasting ways*

# CRANES AND ALLIES

**CLASS** Aves
**ORDERS** 1
**FAMILIES** 11
**GENERA** 61
**SPECIES** 212

This ancient bird order, whose members are sometimes known as the misfits of the avian world, comprises a variety of predominantly ground-living birds that prefer walking and swimming to flying. Some species have, in fact, altogether lost the ability to fly. Descended from a ground-dwelling shorebird, cranes and their relatives have filled a variety of ecological niches around the world. They typically nest on the ground or on platform nests in shallow water. Most have loud calls, and in some cases the male and female perform duets. In parts of Asia, cranes are symbols of good luck and long life; one captive crane is known to have lived to the age of 83.

**Widespread** At least one species of this group of birds can be found on every continent except Antarctica and on many islands. They live in wetlands, deserts, grasslands, and forests. Trumpeters and limpkins occur only in the New World, the majority of bustards inhabit Africa. Some unusual gruids have very narrow ranges.

**Pick me** Two crowned-cranes (*Balearica regulorum*) (left) perform an elaborate courtship dance, involving bowing and head shaking. Other related species have even more bizarre mating rituals, featuring such displays as inflated throat sacs

**Surprise discovery** The once-abundant takahe (above) was rediscovered in an inaccessible valley in New Zealand in the 1940s, after not having been sighted for 50 years. This secretive, flightless bird is one of many unusual species in this group.

## FACT FILE

**White-naped crane** This crane, which stands out with its colorful head, builds flat nests made of dry grass, which it places on slightly elevated ground among marshes. It can often be found in cultivated rice fields

up to 5 ft. (1.5 m)
2–3
Sexes alike
Migrant
Vulnerable

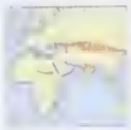
N.E. Asia

**Siberian crane** Unlike most cranes the Siberian crane has a flute-like voice and often wades in shallow waters. It does not breed until it is 5 to 7 years old. It is very wary and difficult to approach. Nests are built near water

2
Sexes alike
Migrant
Critically endangered

N.E. Siberia to Iran, N.W. India & China

**Demoiselle crane** This bird is often seen foraging and nesting close to human settlements. The demoiselle crane eats vegetable matter, insects and other invertebrates. The young remain with both parents until they are thoroughly [illegible]



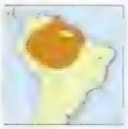
## FACT FILE

**Barred buttonquail** Although this bird generally lives at lower elevations it can be found in mountains up to 7,500 feet (2,273 m) in the Himalayas. It often forages for food in sugarcane, tea, and coffee plantations.

Up to 7 in (17 cm)
3–5
Sexes differ
Sedentary
Common

S., S.E. & E. Asia to Philippines & Sulawesi

**Hoatzin** This prehistoric-looking bird has an extraordinarily large crop. Just a few days after hatching, chicks can climb trees using their feet, bills, and specially adapted wings; the wings have "claws" that later disappear.



Up to 27 in (70 cm)
2–4
Sexes alike
Sedentary
Locally common

N. South America

**Limpkin** The sole species within its family, the limpkin, which is closely related to cranes, uses its long, curved bill to extract snails from their shells. It builds large, bulky nests of rushes and sticks. Before it was protected, hunting had reduced its numbers.

27 in (70 cm)
5–7
Sexes alike
Sedentary
Locally common

C. America to N.E. South America, West Indies

## CRANE'S TRACHEA

Cranes can make a wide range of calls, from purrs to screams. Their very long tracheas are coiled and fused with their sternums. In that region, the bony rings of the trachea are like thin plates that vibrate, amplifying the sounds produced in the voicebox and allowing the voice to carry for more than 1 mile (1.6 km) in some circumstances. Crane species with better developed tracheas make higher pitched calls.

Small buttonquail
*Turnix sylvatica*

Despite their quail-like appearance, buttonquail have only three toes and females are more brightly plumaged than males

Barred buttonquail
*Turnix suscitator*
♀

Hoatzin
*Opisthocomus hoazin*

After attracting a mate, a female buttonquail leaves him to incubate and rear the young, and goes off to find another

♂

Barred buttonquail
*Turnix suscitator*

The relationships of the strange, fowl-sized hoatzin are unclear; some research even associates them with cuckoos

White-breasted mesite
*Mesitornis variegatus*

Subdesert mesite
*Monias benschi*

Gray-winged trumpeter
*Psophia crepitans*

Limpkin
*Aramus guarauna*

Inaccessible rail
*Atlantisia rogersi*

Swamphens flick their tails to flash the white underside as they walk about feeding in wetlands and on verges; this is a social signal to others in their group

Horned coot
*Fulica cornuta*

Coots are the most aquatic of all rails

Purple swamphen
*Porphyrio porphyrio*

Corn crake
*Crex crex*

White-breasted waterhen
*Amaurornis phoenicurus*

Little crake
*Porzana parva*

Takahes live on high moors in the mountains of southeast New Zealand, digging out and eating the fleshy bases of tussocks of grass and sedges

Gray-necked wood-rail
*Aramides cajanea*

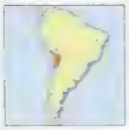
Takahes have such vestigial wings that they cannot fly

Takahe
*Porphyrio hochstetteri*

Wood-rails have very slender bodies and long legs, enabling them to run very quickly through dense undergrowth

## FACT FILE

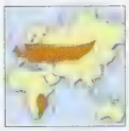
**Horned coot** This aquatic bird builds a huge cone-shaped nest that rises above the water on a base of pebbles or sticks over 3 feet (1 m) high. It can swim and dive well with its lobed toes



Up to 21 in (53 cm)
3–5
Sexes alike
Sedentary
Vulnerable

High Andes of C.W. South America

**Corn crake** Active at twilight, this bird spends most of its time in tall grasses. It lays up to two clutches in a nest on the ground, amid vegetation. It eats invertebrates, plants, seeds, and grain.



Up to 12 in (30 cm)
8–12
Sexes alike
Migrant
Vulnerable

W. & C. Eurasia, S.E. Africa

**Takahe** The largest living member of the rail family, the flightless takahe uses its wings only in displays of courtship or aggression. Usually only one chick from each clutch will survive its first winter.

Up to 25 in (63 cm)
1–3
Sexes alike
Non-migrant
Endangered

S.W. South Island (New Zealand)

## RAILS AND PREDATORS

A high proportion of island-based rail species cannot fly and are therefore vulnerable to over-predation by introduced animals such as rats. Reintroduction programs have helped some species recover

***Back from the brink*** *The Lord Howe rail had fallen to 10 breeding pairs, but has been bred in captivity and released successfully*

## CONSERVATION WATCH

**Victims of agriculture** Once quite common in hayfields across Europe and northern Asia, corn crakes have declined as a result of mechanized farming methods. Due to similar land-use changes imminent in the former Soviet satellite countries, the corn crake is considered vulnerable.

## FACT FILE

**Sunbittern** The sunbittern forages along forest rivers and streams. Its nuptial display involves perching on a conspicuous branch and fanning its colored wings and tail

Up to 19 in (48 cm)
1–2
Sexes alike
Sedentary
Vulnerable

C. & N. South America

**Great bustard** Primarily a herbivore, this bird nests on the ground, laying a small clutch of two to three eggs that the female incubates. The young can fly within 5 weeks and are fully independent in 12–14 weeks

Up to 31/3 ft (1.05 m)
2–3
Sexes differ
Sedentary
Vulnerable

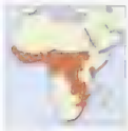
Europe, C. & E. Asia

**Denham's bustard** When alarmed, this and other bustards often crouch and are difficult to see. Its elaborate ornamental plumes are used in nuptial displays. One male has many mates.

Up to 31/4 ft (1 m) (male)
1–2
Sexes alike
Partial migrant
Locally common

[illegible] to C. S. Africa

**African finfoot** This secretive bird forages for invertebrate prey in slow-flowing waters, pumping its neck and head backward and forward with each leg stroke. When alarmed, it may drop into the water, leaving only its head and neck exposed



Up to 23 in (59 cm)
[illegible]
Sexes alike
Sedentary
[illegible]

[illegible]

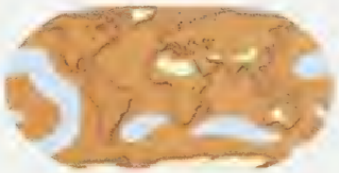
## CONSERVATION WATCH

**Perils of ground-living** A greater proportion of species of cranes and their allies are under threat than any other major bird group. IUCN lists 23 species as endangered (7 of them critically), 28 as vulnerable, and [illegible] as extinct. All species in the group feed and nest on the ground, and are vulnerable to both habitat alienation and predation

# WADERS AND SHOREBIRDS

| | |
|---|---|
| **CLASS** | Aves |
| **ORDERS** | 1 |
| **FAMILIES** | 16 |
| **GENERA** | 86 |
| **SPECIES** | 351 |

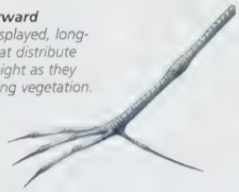
The world's shallow waters and shorelines teem with marine and terrestrial creatures that this order of generally sociable birds has evolved to hunt. The groups within the order exhibit significant diversity, allowing them to exploit different resources within aquatic habitats. Typical waders such as sandpipers and plovers patrol shallow waters and shorelines. Gulls scavenge along shorelines, too, but they are also adapted to swim out to feed on the surface of deeper water. Terns venture even further from shore and dive for food. Auks swim underwater after their prey, much like penguins. The eyes of many waders and shorebirds are set on the sides of the head to scan for predators.



**Watery world** Some species in this group live next to oceans, along estuaries or seashores; others can live far inland in arid climates, in mid deserts.

**Walking on water** Jacanas (above) are distinctive birds that can walk across the surface of still waters by stepping on large lily leaves with their specially adapted feet.

***Best foot forward***
*Jacanas have splayed, long-nailed toes that distribute their body weight as they walk on floating vegetation.*



## A WORLD OF DIFFERENCES

Birds within this order exhibit many anatomical differences, as befits their respective niches. Those that scavenge along the mud flats and in the shallows, probing for food, tend to have long, thin legs and long necks and bills. Those that patrol the surf are usually shorter and can scurry out of the way of incoming water. Birds that swim out and scoop up food on the water's surface tend to be stouter and to have webbed feet.

Species that search for marine prey further out over the water are more capable fliers: they have shorter legs and smaller feet, but long, narrow wings. Terns are very agile, and have long, forked tails for quick maneuvering in the air.

Auks have webbed feet set well back on their compact bodies, and use their wings as flippers underwater.

The diets of these birds range from insects and worms to fishes and crustaceans. Some are scavengers.

**Holes in the ground** Like many waders and shorebirds, puffins (right) often nest in colonies on the shore. Few birds in this order build elaborate nests; like puffins, many lay eggs in holes that they scrape in the ground. They bring food to their chicks until they can fend for themselves.

**Pirate** The [illegible] *pomarinus* [illegible] their stomach contents as they fly

## FACT FILE

**African jacana** Also known as a lily-trotter, this bird uses a high-stepping gait to walk on floating vegetation without plumbing on its long toes. It gropes under the plants for insects, snails, and other organisms.

Up to 10 in (25 cm)
4
Seven alive
Sedentary
Common

Sub-Saharan Africa

**Eurasian oystercatcher** This elegant bird feeds on molluscs and other invertebrates that it catches along seashores. It gathers in large flocks. A strong flier, it can also swim and dive.

Up to 18 in (46 cm)
3–8
Seven alive
Migrant
Common

Europe, W. Siberia, S & E. Asia, N.W., N. & E. Africa

**Beach stone curlew** This birds extremely large yellow eyes help it find crabs and other shellfish on the reef's muddy seashores and sandy beaches. It patrols at night. Its call is harsh and eerie. It scrapes a nest in the sand.

Up to 22 in (56 cm)
1
Seven alive
Sedentary
Vulnerable

Maps: Indonesia, Philippines, New Guinea, N.E. Australia

## BILLS OF FARE

Bills vary with diet and feeding habits. Plovers have big pointed tips, perfect wedges that help them hold and carry food underwater. Wading birds such as spoonbills have long, slender bills for probing and sorting out edible prey, while shore birds, Curlews have short bills with flat sides for hearing carrion.

The elegant jacana of tumbled [illegible] in the [illegible] marshes, they live and nest on floating vegetation [illegible] tiny insects. They are prevented from sinking by their very long toes.

African jacana
*Actophilornis africanus*

Greater painted-snipe
*Rostratula benghalensis*

♀

♂

Pheasant-tailed jacana
*Hydrophasianus chirurgus*

Eurasian oystercatcher
*Haematopus ostralegus*

Crab plover
*Dromas ardeola*

Irisbill
*Ibidorhyncha strutneri*

Black-winged stilt
*Himantopus himatopus*

Pied avocet
*Recurvirostra avosetta*

Found in all inhabited continents, long-legged, these curlews lie, wade in shallow water and stalk in waters to feed on aquatic invertebrates.

Beach stone curlew
*Esacus magnirostris*

## FACT FILE

**Southern lapwing** This bird frequents damp meadows and agricultural fields, where it catches insects and other small prey. Its nests are scraped in the ground that it lines with a thin layer of grass.

Up to 15 in (38 cm)
4–6
Sexes alike
Detention
Common

N. E. & S. South America

**Spotted redshank** A shy, solitary bird generally found only in the company of other waders. It lives near fresh, brackish, or salt water on heath and marshes, and tundra when breeding.

Up to 13 in (30 cm)
3–5
Sexes alike
Migrant
Locally common

Subarctic Eurasia to S. Asia & C. Africa

**Common snipe** The normally secretive common snipe flies in a characteristic zig-zag flight pattern with its bill pointing downward. The tip of the bill has nerve endings that allow the bird to find insects, mollusks, and other food by touch.

Up to 10 in (25 cm)
2–5
Sexes alike
Migrant
Common

North & Central America, Eurasia to C. Africa

## FLIGHT OF THE SNIPE

Common snipes have a conspicuous display involving "drumming" flight. From a considerable height, the male dives steeply with wings, breast and tail ruffled. The outer tail feathers are held apart from the rest. They vibrate and produce the drumming sound as the bird falls through the air. The sound [illegible]

Heading down

## FACT FILE

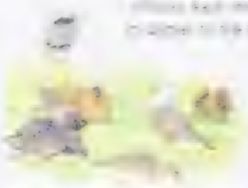
**Green sandpiper** This bird's name [illegible] have a greenish sheen in summer. It makes [illegible] heavily plumed along [illegible]

**Red-necked phalarope** The smallest of the three phalarope species, this bird [illegible] and [illegible] in flocks of [illegible] at sea, and swims gracefully, [illegible] its head high and nodding.

**Ruff** In spring, the ruff can be seen in flocks of hundreds. The female, or reeve, builds a nest out of fine grasses, either among thick grass or in humps of sedge or rushes.

## RUFFING IT

[illegible]



Common greenshank
*Tringa nebularia*

Green sandpiper
*Tringa ochropus*

This species breeds in the swampy woodlands of Eurasia and migrates to Africa and Southeast Asia for winter

Ruff, male on the [illegible] bill, dark and [illegible] breast, radiate breeding plumage

Little stint
*Calidris minuta*

Curlew sandpiper
*Calidris ferruginea*

Other phalaropes spend winter at sea. Our red species migrates from its breeding grounds in the North American midwest to the lakes and mudflats of Andean South America

Wilson's phalarope
*Phalaropus tricolor*

Red-necked phalarope
*Phalaropus lobatus*

Ruff in full breeding regalia. Ruffs congregate in leks at the beginning of breeding to attract and mate with females

Reeves look like ruffs in non-breeding plumage, this is the plumage they wear at their winter quarters from Africa to Southeast Asia

♂

♀

Ruff
*Philomachus pugnax*

**Gray-breasted seedsnipe**
*Thinocorus orbignyianus*

Seedsnipes browse on the tips of low marshy vegetation in the South American highlands

**Black-faced sheathbill**
*Chionis minor*

A fatty layer keeps the bird warm and gives it a chubby look

A rudimentary spur on the wing is used as a weapon

**White-eyed gull**
*Larus leucophthalmus*

Breeding birds have black heads; out of breeding, the head molts to white

Jaegers are parasitic; they live in cold seas and chase other seabirds for scraps

**Bonaparte's gull**
*Larus philadelphia*

**Long-tailed jaeger**
*Stercorarius longicaudus*

**Plains-wanderer**
*Pedionomus torquatus*

Once thought to be a buttonquail, this Australian bird is now know to be a wader related to the South American seedsnipes

Great black-backed gulls are omnivorous, and usually breed in small colonies

**Great black-backed gull**
*Larus marinus*

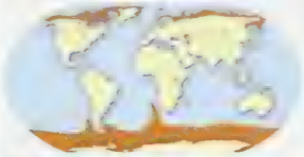
**Herring gull**
*Larus argentatus*

In Europe and North America herring gulls can be [illegible] from other large gulls [illegible] combination of a pale gray ba[illegible] with black-tipped wings, pinl[illegible] legs, and pale [illegible]

## FACT FILE

**Long-tailed jaeger** Like other jaegers, the long-tailed jaeger has aerobatic courtship flights. Its nest is an unlined shallow hollow on the ground. This bird eats lemmings at nesting grounds.

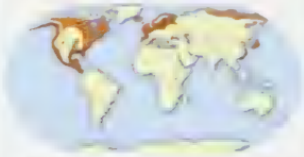
- Up to 21 in (53 cm)
- 2
- Sexes alike
- Migrant
- Common



Arctic, Antarctic, N. & S. Pacific & Atlantic oceans

**Herring gull** This large, familiar gull can be seen at harbors and on beaches as well as at garbage dumps and in ploughed fields. It flies inland to bathe in fresh water, and roosts communally.

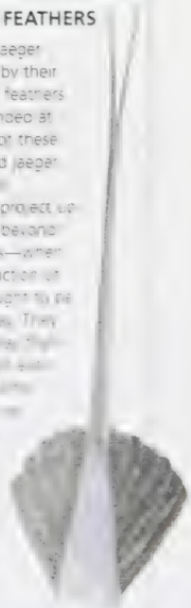
- Up to 26 in (66 cm)
- 2–3
- Sexes alike
- Partial migrant
- Common



North & Central America, W., N. & E. Eurasia

## JAEGER TAIL FEATHERS

The three species of jaeger are easily recognized by their elongated central tail feathers that taper or are rounded at the tip. The smallest of these birds is the long-tailed jaeger. It grows its central tail feathers—which can project up to 10 inches (25 cm) beyond the other tail feathers—when it is an adult. The function of these feathers is thought to be connected with display. They seem to assist in [illegible] Pomarine jaegers [illegible] use them [illegible] breeding [illegible] they [illegible] in normal flight.



**Untold tale**

[illegible]

## FACT FILE

**Fairy tern** [illegible]

Up to 10½ in (27 cm)
1–2
Sexes alike
Partial migrant
Vulnerable

[illegible]

**Little tern** [illegible]

[illegible]

[illegible]

**Common tern** [illegible]

[illegible]

[illegible]

### DIVING TERNS

[illegible]

In skimmers, the lower bill is longer than the upper. They feed by flying just above rather still water with the lower bill immersed, ready to snap up any fishes that come in contact

## FACT FILE

**Common murre** The most widespread of the auk group, common murres nest in large colonies on rocky headlands and offshore islands. The male accompanies the young after they fledge.

- 16 to 19 in (41 cm)
- 1
- Sexes alike
- Locally nomadic
- Common

N. Pacific & N. Atlantic Oceans

**Atlantic puffin** In summer, the Atlantic puffin's beak is red, blue, and yellow. In winter, part of the beak is shed; the remaining part is gray-brown with a yellowish tip. Puffins nest in colonies, sometimes using burrows dug by rabbits or shearwaters.

- up to 14 in (36 cm)
- 1
- Sexes alike
- Partial migrant
- Common

Arctic, N. Atlantic Oceans

## A LONG WAY DOWN

Murres typically lay just one egg at a time on precarious-looking bare rock ledges on coasts and cliffs. Unlike most eggs, which are oval, murre eggs are pear-shaped. Therefore, if dislodged, they will roll around in a small circle.

## CONSERVATION WATCH

**Auk family** The great auk became extinct in the 19th century. The other 24 species of the auk family, the IUCN lists 1 as extinct, 4 as near-threatened, and 1 as vulnerable. [illegible] that auk [illegible] Europe [illegible] of the human [illegible] nets and [illegible] pollution, and disturbance [illegible] sources by fishing [illegible]

# PIGEONS AND SANDGROUSE

CLASS Aves
ORDERS 1
FAMILIES 3
GENERA 46
SPECIES 327

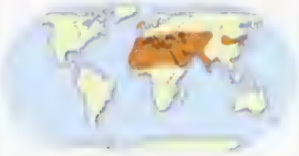
Pigeons and sandgrouse are quite dissimilar and may not even be related. Pigeons and doves are commonplace, tree-dwelling birds that eat fruits and seeds. They have a close association with humans, who have used pigeons for carrying messages. They vary in color from the drab bluish-gray of the familiar street pigeon to the riot of hues that characterize the fruit doves of the Indo-Pacific region. Pigeons feed their young with a milky substance produced in their crops. They also have specialized bills that enable them to suck up water when they drink. By contrast, sandgrouse are dull-colored, fast-flying desert dwellers that are well adapted to arid climates.

**Abundant** Pigeons and doves are found worldwide, except in polar regions. Sandgrouse only inhabit Africa and Eurasia

## FACT FILE

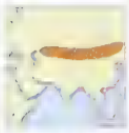
**Rock dove** Also known as a feral pigeon, this bird is familiar to urban dwellers across the world. Originally from Eurasia and North Africa, where it nests on cliffs, it has readily adapted to living on building ledges in cities

Up to 13 in (33 cm)
2
Sexes alike
Sedentary
Common



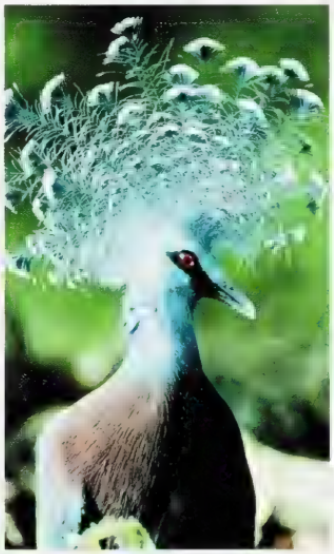
S. Europe, Middle East, S.W. & C.E. Asia, N. Africa

**Pallas's sandgrouse** This rare vagrant bird breeds on open steppes in Central Asia. Each year large numbers fly for long distances outside their main range, to grasslands and beaches, to avoid winter snows that cover feeding areas



Up to 16 in (40 cm)

**Emerald dove** This bird is commonly [illegible] rain forests or swamps, dense vegetation. Where it forages on the [illegible] in pairs, it can [illegible] flying swiftly over open [illegible] between foraging areas



**Crowning achievement** Three species of spectacular crowned pigeons (above) inhabit the rain forests of New Guinea. The world's largest pigeons, they are distinguished by their filmy crests. Pigeon courtship rituals include bowing and special display flights

**Side by side** Like other species in this group, green-pigeons (above, left) roost communally. Highly social birds, pigeons, doves, and sandgrouse often flock in very large groups numbering in the thousands

Madagascar green-pigeon
*Treron australis*

The Indo-African green-pigeons are arboreal fruit-eaters that have a gizzard modified for grinding seeds as well as fruit

Black-backed fruit-dove
*Ptilinopus cinctus*

Fruit-doves have thin-walled gizzards to allow the ingestion of fruit and the passing of seeds

Seychelles blue pigeon
*Alectroenas pulcherrima*

Bruce's green pigeon
*Treron waalia*

The turkey-sized crowned pigeons of New Guinea have a uniquely fan-like crest

Victoria crowned pigeon
*Goura victoria*

Mourning dove
*Zenaida macroura*

Gray-headed dove
*Leptotila plumbeiceps*

Zebra dove
*Geopelia striata*

## FACT FILE

**Madagascar green-pigeon** This handsome, fruit-eating bird is one of several species of green-pigeon. It spends most of its time in trees and bushes, climbing in the manner of a parrot. It has complex, soft calls that are not typical of pigeons and doves.

Up to 13 in (32 cm)
2
Sexes alike
Sedentary
Locally common

Madagascar & Comoro Is

**Mourning dove** This dove's name derives from its low, mournful, cooing call. It is a strong, fast flier that may fly considerable distances to find feeding areas or the nearest water source, often at dawn or dusk.

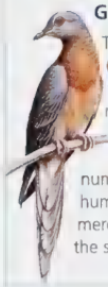
Up to 14 in (34 cm)
2
Sexes alike
Partial migrant
Common

North & Central America, West Indies

**Victoria crowned pigeon** The only crowned pigeon with a white-tipped crest, the Victoria crowned pigeon lives in lowland rain forest. Hunted for food, it remains common only in remote areas of northern New Guinea.

Up to 29 in (76 cm)
1
Sexes alike
Sedentary
Vulnerable

Lowland N. New Guinea



## GONE FOREVER

The passenger pigeon (*Ectopistes migratorius*) was one of the world's most plentiful birds, seen across North America in flocks that may have numbered in the billions. But humans hunted them mercilessly, and the last of the species died in 1914

## CONSERVATION WATCH

**And still going...** Among pigeons, the IUCN lists 11 species as critically endangered, 5 as endangered, and another 30 as vulnerable. Habitat destruction and hunting are root causes. The passenger pigeon, dodo, solitaires, Socorro dove, and choiseul pigeon are all extinct.

# PARROTS

CLASS: Aves
ORDERS: 1
FAMILIES: 1
GENERA: 85
SPECIES: 904

Parrots and cockatoos form an ancient and highly distinct order of birds. They are easily recognized by their short, blunt bills, which have downcurved upper mandibles, and also by their feet, which have two toes pointing forward and two pointing backward. Although some species are dull, most have brilliantly colored plumage, predominantly in shades of green accented by splashes of red, yellow, and blue. Their visual appeal is one reason for their popularity as pets over the centuries. Another is their antics: they can perform acrobatics, hanging on to perches with their feet or bills. They can also mimic human voices.

**Southerly distibution** Parrots live primarily in the Southern Hemisphere. They are most common in tropical rain forests, especially lowland tropical rain forests, but some species prefer open, arid regions. The highest concentrations of species occur in Australasia and South America. The most southerly parrot inhabits Tierra del Fuego.

**Group dynamics** This colorful gathering of orange-checked (*Pionopsitta barrabandi*) and blue-headed (*Pionus menstruus*) parrots (above) is typical of these very gregarious birds. Parrots often forage and roost in small groups or large flocks consisting mainly pairs or family groups.

**Fancy feathers** Red-and-green macaws (*Ara chloroptera*) (below), though difficult to see among the forest canopy, can be recognized by their colorful plumage and long tails. Their tapered wings allow them to fly faster than would otherwise be expected for birds of their size.

**Open wide** Parrots can have a greater range of motion and are more powerful than the bills of other birds. A well-developed hinge on the upper mandible of a parrot's jaw further provides leverage that enables the bird to use its bill to climb, manipulate, and a strongly muscled, cutting-edged lower mandible to crack open large, hard-shelled nuts.

*Inner view* The cutaway [illegible] upper bill when [illegible]

***Aloft*** *Two brilliantly colored red-and-green macaws display a rainbow of hues when they fly. They are among the largest parrots.*

## A SOCIABLE GROUP

Most parrots eat seeds and nuts (which they crack open with their heavy bills) as well as fruit. They forage among the treetops or on the ground. Lorikeets, on the other hand, are strictly arboreal; they eat soft fruit, and harvest pollen and nectar from blossoms.

Although parrots' basic features differ little among species, there is considerable variation in size and shape. Wings can be narrow and pointed, or broad and rounded. Similarly, tails may be long and pointed or short and squarish. Some have ornate feathers. Cockatoos, a separate family from "true parrots," have prominent, erectile head crests. The sexes are usually alike.

Parrots are very social birds. They squawk loudly and frequently, and are heard more readily than observed in the wild. They can be difficult to glimpse as they fly through the forest canopy, camouflaged by their green plumage. That has not stopped many of them from falling prey to poachers, who sell them to the worldwide pet market. That and habitat destruction have made parrots one of the most common groups of birds on lists of threatened species.

## FACT FILE

**Kea** This is one of the world's only critical parrots, its moving, inquisitive, curious and even playful nature is manifest in lots of ways. Keas are omnivorous, carrion, and sheep-fattening accounts for species of killing them because.

Habitat: South Island, New Zealand

**Galah** This bird feeds in trees during the hot middle hours. It eats seeds and other plant material, grubs on the ground, as well as insects and their larvae. The galah is seen throughout Australia and inland.

Habitat:

## DOMESTICATION OF PARROTS

The familiar budgerigar (Melopsittacus undulatus) is one of the world's most popular pet species, on par with pigeons. They began to be sold in captivity in the middle of the 19th century. Other popular domesticated parrot species include cockatiels and lovebirds. Although pet parrots can mimic human speech, they do not understand a word they are saying.

**Tame** is the which existing endangered pet species (pet green and red-collared macaws, the blue and gold macaw, and the hyacinth macaw).

## CONSERVATION WATCH

**It's criminal** Illegal trafficking for the pet trade threatens a worrying amount of rare species. Even eggs of these species are stolen from the wild, or by filmed, killing, and sadly in instances, the hunting, they are then further selling. The IUCN has 3 species in its endangered, 23 as endangered, and 60 as vulnerable. The trade [illegible] and transportation, both in and out of [illegible]

## FACT FILE

**Alexandrine parakeet** [illegible]

Sedentary
Locally common

**Blue-crowned hanging parrot** This [illegible]

## BLUE VARIATIONS

[illegible]

*Sonnerat's cut*

## CONSERVATION WATCH

**Fischer's lovebird** This beautiful, [illegible]

Thick-billed parrot
Rhynchopsitta pachyrhyncha

Blue-and-yellow macaw
Ara ararauna

Hyacinth macaw
Anodorhynchus hyacinthinus

Measuring two meters in open rainforest nuts and fruits

White-eared parakeet
Pyrrhura leucotis

Scarlet macaw
Ara macao

Military macaw
Ara militaris

Nanday parakeet feed on seeds and fruits measure the ground

Nanday parakeet
Nandayus nenday

Burrowing parakeet
Cyanoliseus patagonus

## FACT FILE

**Thick-billed parrot** The bulk of the species is due to losing habitat and poaching as this mature. The parrot eats pine seeds, pinion nut, and acorns. It gathers in enormous flocks of about half a dozen up to several hundred birds.

In Mexico

**Hyacinth macaw** The parrot from the largest species, the Hyacinth macaw is far less common than it once was due to trafficking in the cattiond trade and hunting for food and feathers. Males are slightly larger than females.

In S. & C. South America

**Scarlet macaw** This brightly colored bird sometimes supplements its diet and nut diet with nectar and flowers. It also sometimes ingests clay to aid in the digestion of the hard chemicals found in the unripe fruit that it eats before other birds can get to it.

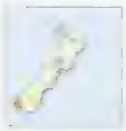
C. & N. South America

## BURROWING PARROT

Most parrots nest in tree hollows or in cavities in structures such as termite mounds. The burrowing parrot of northern Argentina, on the other hand, excavates deep burrows in cliffs and banks along rivers or near the ocean. These offer protection from predators.

## FACT FILE

**Kakapo** The world's heaviest parrot is nocturnal and cannot fly because it lacks a sternal keel. It chews leaves or stems to extract their juices. Males court females by booming with their inflated gular air-sacs



Up to 25 in (64 cm)
1–3
Sexes alike
Sedentary
Extinct in natural range

S. W. South Island, New Zealand; introd. to Little Barrier, Maud, Codfish & Pearl Is

**Blue-fronted parrot** This arboreal, climbing parrot lives in forests and builds its nests in hollows in trees. It lays a clutch of two eggs, which are incubated mainly by the female over the course of about 25 days

Up to 15 in (37 cm)
2–4
Sexes alike
Sedentary
Common

N.E. & C. South America

**Monk parakeet** This highly adaptable South American species is found in city parks, on farms and in gardens as well as in savannas, forests, and palm groves. Unlike other species of parrots, it builds its own rather complex nests of twigs

Up to 12 in (29 cm)
1–11
Sexes alike
Sedentary
Common

[illegible] South America

## STRIKING RUFF

The hawk-headed parrot (*Deroptyus accipitrinus*) of Amazonia has a striking ruff of long, colorful erectile feathers on the nape. It raises them when it is excited or angry. It is a noisy, sociable, and conspicuous parrot that usually inhabits jungle interiors and edges, often along watercourses.

*Head on*
*A raised collar*

*In profile*

Red-fan parrot
*Deroptyus accipitrinus*

White-crowned parrot
*Pionus senilis*

Monk parakeet
*Myiopsitta monachus*

Canary-winged parakeet
*Brotogeris versicolurus*

Orange-winged parrot
*Amazona amazonica*

Cuban parrot
*Amazona leucocephala*

Blue-fronted parrot
*Amazona aestiva*

Kakapo
*Strigops habroptilus*

Flightless, has cryptic plumage to help it hide in its scrubby habitat, but this has not stopped introduced stoats, rats, and feral cats from exterminating it in its natural range

Like other parrots, the kakapo's feet have two toes forward and two toes back

# CUCKOOS AND TURACOS

**Here, there and everywhere** Turacos inhabit savannas and forests. They live only in Africa, south of the Sahara. Cuckoos thrive in a variety of habitats—from open moorland to tropical rainforest—and are virtually cosmopolitan, although they predominate in the tropics and subtropics

**CLASS** Aves
**ORDERS** 1
**FAMILIES** 3
**GENERA** 42
**SPECIES** 162

These two old families of birds are related by virtue of some molecular similarities, but otherwise differ markedly in development, anatomy, and other characteristics. Cuckoos are notorious as parasitical birds that trick other species into raising their chicks. However, less than half of the 140 or so species of cuckoos actually engage in such behavior. All cuckoos have feet with two toes pointing forward and two pointing backward, but otherwise they differ considerably among species. Turacos are more homogeneous: with one exception, they are rather slender-necked birds with long tails, short, rounded wings, and erectile, laterally compressed crests.

**Doing away with the competition** A common cuckoo chick (left) hatches before the eggs of its host parent, in this case a reed warbler. Within three or four days, the young cuckoo is strong enough to evict the other eggs or hatchlings so that it can monopolize the foster parent's attention and food. Different females within one species of cuckoo may each be adapted to parasitize one species of host.

## ROBBING THEM BLIND

Some cuckoo species have evolved remarkably devious strategies to get away with their brood parasitism, such as laying eggs that closely resemble those of their host.

Most "true cuckoos" are drab, although the bronze-cuckoos of the Old World tropics are brightly colored. Some cuckoo species are solitary; others breed communally and maintain group territories. Some, such as the roadrunners and ground cuckoos, rarely fly and prefer to run.

Turacos are gregarious, noisy birds whose harsh, barking alarm calls can be heard from afar. They gather in small groups and glide or flap from tree to tree. They are more agile when running among the branches than when flying.

The savanna-based turaco species have dull plumage, but those that favor forests tend to be brightly colored, with special blue-green pigments that are water-soluble. Turacos are primarily herbivorous, but they also eat insects.

**Look at me** Unlike most other birds, whose bright plumage colors are caused by refraction of light, turacos such as the Knysna turaco (*Tauraco corythaix*) (below) of South Africa have true pigmentation

## FACT FILE

**Common cuckoo** This well-known bird inhabits woodland clearings and cultivated fields, where it feeds on insects. It has a familiar call from which its name arose. Its females are polyandrous and parasitic.

- Up to 13 in (33 cm)
- Up to 12, even 20, singly in host nests
- Sexes differ
- Migrant
- Common

Eurasia except S.W., N.W. & S. Africa

**Greater coucal** This non-parasitic bird has terrestrial habits. It is often mistaken for a game bird due to its size and voluminous tail. It has a distinctive dull, booming call, as well as a variety of croaks and chuckles.

- Up to 20 in (52 cm)
- 2–4
- Sexes alike
- Sedentary
- Common

S. & S.E. Asia, Greater Sundas, some islands off Philippines

**Greater roadrunner** This ground-loving bird is the basis for the famous cartoon character. It inhabits arid regions and deserts with shrubs and cacti. It uses its long tail as a rudder to change direction when it runs quickly. Its diet includes snakes and other reptiles.

- Up to 22 in (56 cm)
- 2–6
- Sexes alike
- Sedentary
- [illegible]

S.W. USA to C. Mexico

## FURRY FEAST

Old World cuckoos eat insects and their larvae. They are especially fond of hairy caterpillars, which are shunned by many other birds. Their diet forces European cuckoos to migrate to Africa for the winter.

Common koel
*Eudynamys scolopaceces*

Dideric cuckoo
*Chrysococcyx caprius*

One of the bronze cuckoos, this species has the characteristic brilliantly glossed green back of the group

Greater coucal
*Centropus sinensis*

Common cuckoo
*Cuculus canorus*

A female common cuckoo about to place her egg in the nest of another bird—in this case, a reed warbler

Yellow-billed cuckoo
*Coccyzus americanus*

Feeds on insects on the floor of rain forests, but roosts and nests in trees

Bornean ground-cuckoo
*Carpococcyx radiceus*

Rufous-vented ground-cuckoo
*Neomorphus geoffroyi*

High-ridged bill for parting vegetation as bird forages for foliage

Smooth-billed ani
*Crotophaga ani*

Greater roadrunner
*Geococcyx californianus*

Omnivorous, and an efficient predator on small reptiles, also eats insects, mice, and the eggs of other small birds

# OWLS

CLASS Aves
ORDERS 1
FAMILIES 2
GENERA 29
SPECIES 195

Solitary creatures of the night, owls are instantly recognizable by their forward-facing eyes, face masks, and stout silhouettes. There are two families of owls: barn owls, with heart-shaped faces and elongate bills, and "true owls," with rounded heads and hawk-like bills. They usually roost in out-of-the-way spots. Even when out in the open, they tend to perch stoically, camouflaged by their mottled, earth-toned plumage, so they are more often heard than seen. Their mysterious nocturnal habits, coupled with their far-reaching hoots and other sometimes eerie-sounding calls, have given rise to many folk superstitions. In lifestyle, however, they are no more than nocturnal birds of prey.

**Cosmopolitan birds** Both families of owls are widespread; some species such as the barn owl are among the most widely distributed of all birds. Most species inhabit woodlands and forest edges, but some prefer treeless habitats instead

**Hungry mouths to feed** A great gray owl (above) feeds a rodent to its chicks. Some owls vary their breeding seasons and clutch sizes according to availability of food. Hatching may be asynchronous, so that if not enough food is available for all offspring, the more-developed chicks can survive by eating their younger siblings.

**STEREO HEARING**
Many owls have ears that are asymmetrical in both size and shape. This structure enables them to more precisely locate their prey, by noting the subtle difference between the sound signals reaching each ear.

**Stealthy flight** The eastern screech owl (*Otus asio*) (right) has soft, loose plumage. Its flight feathers have frayed rather than smooth edges, which slows the flow of air over the wings and silences flight

***Silent flier***
*The eastern screech owl's wings allow it to make less noise when it swoops down to strike unsuspecting prey*

## NIGHT HUNTERS

Owls, which typically become active at twilight, are well adapted to a nocturnal predatory lifestyle. Their forward-facing eyes give them binocular vision that helps them judge distances well. They can also rotate their heads to see behind them. They can see well in poor light, thanks to their tubular eyes and abundance of light-sensitive rods in their eyes. They also rely on their acute hearing: some species even have facial masks to help them capture sound waves more effectively.

Owls also have sharp, hooked bills and strong legs with talon-tipped feet. They remain on the alert for prey as they perch on branches or ledges, then swoop down to catch the unwary mammal or insect on the ground. They may also snatch insects or mammals from trees, or catch insects in the air.

When they capture sizable prey with their feet, owls sometimes kill it by reaching down to bite it. Small prey is often lifted to the beak with one foot, in the manner of parrots, and swallowed whole. Larger prey is held with the feet and torn apart with the bill before being eaten.

Owls flatten their plumage to become less conspicuous when they are disturbed. Several species have erectile feathers that resemble "ears," which they raise in emotion.

In most species, females are larger than the males, sometimes weighing twice as much as their mates. The young often leave the nest well before they [illegible] their parents continue to feed them until they can fend for themselves.

All owls call, especially as the breeding season approaches, and species are often named for the typical sounds they make. A few owl species almost sing.

## FACT FILE

**Great gray owl** This large bird sometimes uses the abandoned nests of other birds. It may lay as many eggs in years when food is particularly scarce, whereas in good years, it may lay up to nine eggs.

N North America, N. Eurasia

**Snowy owl** This bird migrates during the winter, when it may be found on lake shores, in marshland, or by the sea. It perches on rocks or in trees, and kills its prey—invertebrates, small mammals, or birds—by pouncing in flight.

N. Eurasia, N. Canada, Alaska

## PYGMY OWL DISGUISE

Owls protect themselves from predators primarily by camouflaging themselves against their surroundings and by keeping out of sight. Their nocturnal habits also put them on a different schedule than most bird predators. As further protection, many pygmy owls have spots on the back of their heads that resemble eyes. These are thought to confuse predators into thinking that the owl is greeting them of their presence.

*Eyes on the back of its head?*

Great horned owl
*Bubo virginianus*

Verreaux's eagle-owl
*Bubo lacteus*

The size of a buzzard, and one of the largest owls, common across sub-Saharan Africa, it preys on medium-sized mammals and rather large birds.

Tropical screech-owl
*Otus choliba*

Spectacled owl
*Pulsatrix perspicillata*

Barn owl
*Tyto alba*

Comb-like centre toenail is used for preening.

Has the shortest "ears"—horn tufts above the eyes—of its group. Lives in open country and hunts mostly small mammals.

Short-eared owl
*Asio flammeus*

Northern long-eared owl
*Asio otus*

Boreal owl
*Aegolius funereus*

The paler member of a group of small, mostly tree-living owls with incomplete facial disks.

Burrowing owl
*Athene cunicularia*

Northern saw-whet owl
*Aegolius acadicus*

## FACT FILE

**Barn owl** One of the most widespread birds in the world, the barn owl can often be seen flutting towards in the glare, shoulders and meadows of high ground. Barn owls have exceptional hearing, and can catch prey in total darkness, guided by sound alone. They also occasionally hunt in daylight.

- Up to 1 million
- 4–7
- Declining
- Endangered
- Common

1. North, Central America, and Central Africa to Europe to Australia

**Northern long-eared owl** This bird sometimes nests in squirrels' nests. The young are fed by the female, although it is the male that does most of the hunting and delivers their diet of small mammals, birds, and invertebrates. Females are generally darker and larger than males. Eye color varies over the region, from yellow to golden.

- Up to 1 million
- 5–7
- Never alive
- Partial migrant
- Locally common

1. Most Northern America, N. to E. temperate Eurasia

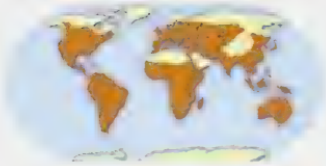
## LONG-EARED OWL

To discourage vulnerable predators from approaching her nest, the female long-eared owl spreads out her wings, fluffs her flight feathers, and lowers her head, making herself appear larger.

# NIGHTJARS AND ALLIES

CLASS Aves
ORDERS 1
FAMILIES 5
GENERA 22
SPECIES 118

Similar to owls in nocturnal lifestyle, this order of birds—which comprises oilbirds, frogmouths, potoos, owlet-nightjars, and nightjars—is thought to be distantly related to them. Like owls, nightjars and their allies are active at twilight and at night. They have soft plumage in patterns and shades that make them difficult to distinguish from the trees or ground. They tend to have rather large heads and large eyes, though the latter are less forward-facing in this group than in owls. Tubular in shape, their eyes are adapted to see well in low light, and they have a keen sense of hearing.



**Diverse habitats** The oilbird is found only in tropical South American caves. Potoos inhabit open woodlands in Central and South America. Frogmouths and owlet-nighjars live in or near arboreal areas in Australasia. Nightjars live in a variety of warm-climate habitats across the world

**Trailing behind** Nightjars (above) have long tails and long, pointed wings that help them fly fast. In ancient times, nightjars were accused of stealing milk from goats, hence their nickname of goatsuckers. In reality, it is the insects that gather around livestock that they pursue.

**Spot the bird** The tawny frogmouth (above) is well camouflaged against its background. These nocturnal birds try to remain inconspicuous during the day. Here one sits motionless on its nest, its shape and color imitating the branch of a tree.

Oilbird
*Steatornis caripensis*

Spotted nightjar
*Eurostopodus argus*

Common potoo
*Nyctibius griseus*

Tawny frogmouth

Camouflages itself at roost by imitating a dead branch plumage pattern is cryptic

## MASTERS OF DISGUISE

These rather unusual-looking nightbirds are experts at blending in and often strike curious poses that make them resemble broken-off tree limbs.

They have broad, flattened bills for catching insects. The bristles that surround the bills help funnel food (insects, fruit, or other animals) into their large mouths.

The oilbird is the only member of its family. It has a fan-like tail and long, broad wings. It is a cave dweller that can navigate in total darkness by relying on echolocation, in a similar way to bats.

Frogmouths are odd-looking birds whose bodies taper from their very large, flat, shaggy heads. Their stout bills, hardened like bones, snap shut to trap their prey.

Potoos resemble frogmouths but have thinner bills and fewer bristles. They eat insects while flying.

Nightjars comprise about half the species in this order. They fly swiftly but have weak legs and feet, which they rarely use. They open and display their brightly colored mouths when they feel threatened.

Owlet-nightjars look like a cross between nightjars and owls. Their broad, flat bills are almost hidden by bristles. They have longer legs and run more than the other birds in this group, and hunt by perch-pouncing.

### CONSERVATION WATCH

**In reasonable shape** Only three species of nightjars and their allies are listed as critically endangered by IUCN, and five as vulnerable, but more may be under threat because so little information is available on these cryptic birds. All the critically endangered species are nightjars found in Jamaica, Puerto Rico, and Central and South America.

Long-tailed nightjar
*Caprimulgus climacurus*

Pennant-winged nightjar
*Macrodipteryx vexillarius*

Males of the *Macrodipteryx* group are polygamous; they grow a pair of prolonged inner flight feathers prior to breeding, which they flaunt in group displays to attract females

Standard-winged nightjar
*Macrodipteryx longipennis*

Common pauraque
*Nyctidromus albicollis*

Common poorwill
*Phalaenoptilus nuttallii*

European nightjar
(Eurasian nightjar)
*Caprimulgus europaeus*

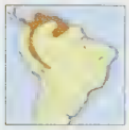
Abyssinian nightjar
*Caprimulgus poliocephalus*

Australian owlet-nightjar
*Aegotheles cristatus*

Watches from perch, waiting to pounce on insect prey

## FACT FILE

**Oilbird** This bird lives in caves, mostly in mountains but also sometimes along rocky coasts. Its cup-like nests are made of regurgitated fruit. It hovers while plucking fruits and seeds, which it locates by sight and by scent.



Up to 20 in (50 cm)
1–4
Sexes alike
Sedentary
Locally common

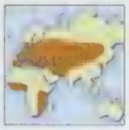
N. & N.W. South America

**Tawny frogmouth** This sociable bird can be seen perching in pairs or in family groups. It searches for food—invertebrates, small mammals, and rodents—on the ground, flying into the trees at any hint of danger.

Up to 21 in (53 cm)
1–3
Sexes alike
Sedentary
Common

Mainland Australia & Tasmania

**European nightjar** This bird's eggs hatch asynchronously in a nest made in a shallow, unlined scrape in the ground. Eggs are color-camouflaged. The adult uses a special display to distract and drive away any predators that approach the nest.



Up to 11 in (28 cm)
1–2
Sexes differ
Migrant
Common

W. & C. Eurasia, W. & S.E. Africa

## OPEN-MOUTHED FEEDING

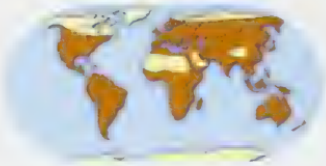
Common nightjars fly quickly through the darkened air, their capacious mouths fully open in order to catch moths, beetles, crickets, and other insects that they pursue with their keen eyesight. Bristles on either side of their mouths help trap their prey.

***Open wide***
*A nightjar catches an insect while flying with its mouth open*

# HUMMINGBIRDS AND SWIFTS

CLASS Aves
ORDERS 1
FAMILIES 3
GENERA 124
SPECIES 429

Any common ancestry between these dissimilar birds would have to be very old indeed. Nevertheless, hummingbirds and swifts do have significant anatomical similarities, such as the relative length of their wing bones. This is related to two distinguishing features for both types of birds: their very rapid wing beats and flight behavior. Hummingbirds are also known for their tiny size, bright iridescent colors, and hovering flight. The average weight of these birds is less than one-third of an ounce (8.3 g); the bee hummingbird is the smallest known species of bird, at a mere one-tenth of an ounce (2.5 g). Swifts are relatively bigger birds that are the fastest fliers of the avian world.



**Prevalent throughout** Swifts are widely distributed, but are most numerous in the tropics. Hummingbirds are confined to the New World; most live in its tropical belt

## FREQUENT FLIERS

Swifts spend most of their time in the air, taking advantage of their narrow, swept-back wings to maneuver after insects, especially swarming species such as mayflies and termites. They also eat bees and wasps. Several species make long migrations over land and stretches of ocean to reach their Southern Hemisphere wintering grounds.

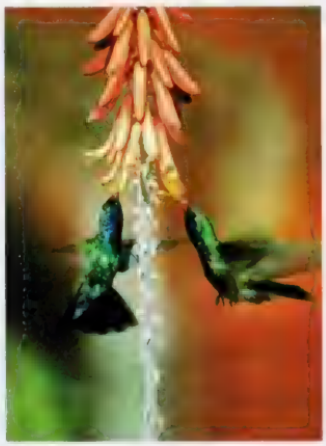
Predominantly dark colored, swifts have short legs with strong claws. Some cave swiftlets nest and roost in total darkness, deep in caves. They are among the few bird species capable of navigating by echolocation, using clicking calls.

Hummingbirds have long, very narrow bills that they poke into flowers for nectar, hovering in front of the blossoms while they collect the sweet substance with their brush-tipped tongues. They also supplement their diet with insects that they eat for protein.

Swifts and hummingbirds can become torpid to conserve energy, lowering their metabolism and body temperatures while resting.

**Compact caretaker** A green hermit hummingbird (*Phaethornis guy*) (above) feeds her chicks. The female usually builds the nest and incubates the chicks. Her nest is a small cup of plant material held together with spider web and sometimes anchored to the underside of a leaf

**Spit it out** The salivary glands of many swifts (left) enlarge during the breeding season. They use secretions from these glands to glue together sticks to form their nests, which they then attach to vertical walls of hollow-tree nesting sites. The nests of some species of cave-dwelling swifts are made entirely of saliva and are highly sought after in some Asian cuisines



**Eating on the fly** Hummingbirds can hover while they feed (right) thanks to the anatomy of their wings. They can turn the wings completely over on the back-stroke as well as on the forestroke, thereby counteracting the tendency to move in any one direction. Their broad tails help them make precise maneuvers

Whiskered tree swift
*Hemiprocne comata*

Tree swifts build half-saucer nests of feathers and bark agglutined with saliva on the open branches of a tall forest tree; the single egg hatches into a cyptically patterned chick

Square tail and broad white rump bar distinguish this species from other related swifts; it feeds at great heights and lives in Africa and Southwest Asia

Little swift
*Apus affinis*

Alpine swift
*Tachymarptis melba*

Breeds at high altitudes across southern Eurasia and migrates to Africa and India; can sleep on the wing

Gray-rumped treeswift
*Hemiprocne longipennis*

Tree swifts fly out from exposed set perches in tree tops to hunt insects; they all have either short crests or white mustache stripes on the face

Common swift
*Apus apus*

The common swift is the most familiar and widespread swift in Eurasia. It nests mostly in cavities in buildings. It migrates to winter exclusively in sub-equatorial Africa

Asian palm-swift
*Cypsiurus balasiensis*

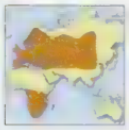
Chimney swift
*Chaetura pelagica*

African palm-swift
*Cypsiurus parvus*

With long forked tail and tapered wings, palm-swifts are the most streamlined of all swifts; they roost and nest mostly in palms

## FACT FILE

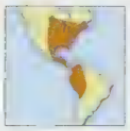
**Common swift** This bird spends most of its time in flight, in urban and rural areas. It is highly sociable and can often be seen flying in chirruping groups. Nestlings are reared by both parents and can fly within 2 months



Up to 7 in (17 cm)
1–4
Sexes alike
Migrant
Common

W. & C. Eurasia, S. Africa

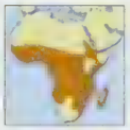
**Chimney swift** This bird can often be heard making high-pitched twittering calls as it flies high overhead. It can often be seen in the company of swallows, a species it resembles but to which it is not closely related



Up to 5 in (13 cm)
2–7
Sexes alike
Migrant
Common

E. North America, N.W. South America

**African palm-swift** This bird's nest is a small, flat pad of seed down that it glues to a leaf. The female then uses saliva to glue one or two eggs to the pad. The parents incubate the eggs in a vertical position. Chicks hook themselves to the pad until they can fly.



Up to 6 in (16 cm)
2
Sexes alike
Sedentary
Locally common

Sub-Saharan Africa, Madagascar

## AERIAL EXISTENCE

Swifts—easily recognized in the sky thanks to their compact bodies and distinctive wing shapes—spend most of their time darting around, perching only at their overnight roosts. They can even copulate in mid-air. The female signals her interest by holding her wings in a V-shape and gliding downward. The male pursues her, then gently lands on her back. They then mate as they glide downward

***Mating***

## FACT FILE

**Crimson topaz** This visually stunning bird is the second-largest hummingbird. It lives in the Amazon region, where it is often found in the forest canopy, making it difficult to observe. The male's long tail feathers cross halfway down its tail.

Up to 9 in (22 cm)
2
Sexes differ
Sedentary
Locally common

N. South America

**Giant hummingbird** The largest bird in this order, the giant hummingbird is the size of a large swift. Its plumage is mostly brown, and quite dull compared to that of most hummingbirds. It has a long, slender bill and a forked tongue.

Up to 9 in (23 cm)
1–2
Sexes differ
Sedentary
Locally common

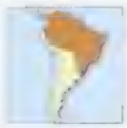
Andean W. South America

**Sword-billed hummingbird** This bird's bill is longer than its body, which makes it the longest bill relative to body length of any bird. The sword-billed hummingbird has co-evolved with the climbing passion flower.

Up to 9 in (23 cm)
Unknown
Sexes differ
Sedentary
Locally common

Andean N.W. South America

**Black-throated mango** This small bird prefers to feed on nectar from red flowers, though it will eat from others also. During courtship flight displays, its wings beat twice as fast as normal.



Up to 5 in (12 cm)
2
Sexes differ
Partial migrant
Common

N.W., N.E. and E. C. South America

## CONSERVATION WATCH

**Habitat crises** IUCN lists 7 species of hummingbirds as critically endangered. All occur in Central America and north South America, where habitat destruction has proved disastrous. Another 7 hummingbird species are endangered, and 11 vulnerable. Swifts, however, have suffered less: only 7 species are considered vulnerable at worst.

Uniquely upturned tip on the bill for accessing nectar; curled, bifurcate tongue snakes out into the nectar in the base of a flower and takes it up by capillary action

Males hold a flower-centered territory year-round, but females only do so when not breeding; the sexes are alike in plumage

**Fiery-tailed awlbill**
*Anthracothorax recurvirostris*

**Purple-throated carib**
*Eulampis jugularis*

**Festive coquette**
*Lophornis chalybeus*

**Fork-tailed woodnymph**
*Thalurania furcata*

One of a group of fork-tailed hummingbirds, this species is widespread in rain forests across northern South America

**Ruby topaz**
*Chrysolampis mosquitus*

**Frilled coquette**
*Lophornis magnificus*

Identifiable by its glistening golden gorget. Iridescent plumage in hummingbirds comes from the physical structure of platelets in the feather barbules

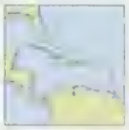
**Racket-tailed coquette**
*Discosura longicauda*

Racket-tipped tail feathers are present in several hummingbirds; tail feathers play an important role in flight maneuvers

**Green-throated carib**
*Eulampis holosericeus*

## FACT FILE

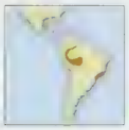
**Purple-throated carib** This bird lives in the Lesser Antilles, in high altitude forests and various other habitats. The female's bill is slightly longer and more curved than the male's. Its cup-shaped nest is camouflaged with lichens



Up to 5 in (12 cm)
2
Sexes alike
Sedentary
Locally common

Lesser Antilles

**Festive coquette** This hummingbird inhabits humid forests and scrub-covered areas. It can be found in the lowlands, at altitudes up to 3,300 feet (1,000 m), east of the Andes from Colombia down to Argentina.



Up to 3¼ in (8.5 cm)
2
Sexes differ
Sedentary
Indeterminate

N.W. South America

**Green-throated carib** This primarily green hummingbird has a thin, curved black bill. It lives mainly in dry low-altitude areas, though it can also be found in higher regions, as well as in mangroves. It sometimes builds its nests quite high up in the branches.

Up to 5 in (13 cm)
2
Sexes alike
Locally nomadic
Locally common

E. Puerto Rico, Lesser Antilles, Grenada

## HIGH METABOLISM

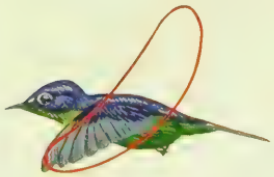
The hummingbird's energy-intensive flying style requires it to have a highly efficient system for obtaining oxygen, as well as the ability to quickly process large amounts of food. It has a huge heart, too, to pump blood to distribute energy to the wing muscles; the heart is proportionally twice the size of that in songbirds. Some species migrate long distances to remain near [illegible] of sweet nectar

***Thirsting for energy***
*A hummingbird d[illegible] long bill into a flower to suck nectar*

# HUMMINGBIRD FLIGHT

Most birds can only fly forward, but hummingbirds can also fly backward, sideways, and straight up or down. They can even switch direction without turning their bodies. They can accomplish this thanks to their specialized physiology and anatomy, with wings that can be turned through 180 degrees. To maintain hovering, they can beat their wings up to 90 times per second. They can also stop and accelerate very quickly. Their flight feathers take up almost the entire wing, and their breastbones are very strong.

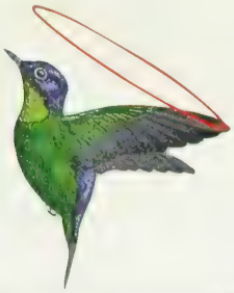
**Hummingbird wing structure** This arrangement transfers enormous power to the flight feathers



**Flying forward** Hummingbirds flap their wings up and down to move forward

**Hovering** Hummingbirds move their wings in a rapid figure-eight motion to hover in place

**Flying upward** By altering the wing angle of the movements, many directional changes are possible. Here, a more up-and-down angle allows a vertical rise



**Flying backward** [illegible] above and behind [illegible] move backward

*Free movement* [illegible]

**Positioning agent** The scintillant hummingbird (*Selasphorus scintilla*) (below) can position itself at just the right angle to reach the nectar in the flower. Then its wings hover at blurring speed to keep it in position, the body quite still.

# MOUSEBIRDS

CLASS Aves
ORDERS 1
FAMILIES 1
GENERA 2
SPECIES 6

The mousebird gets its name from its odd habit of creeping and crawling among bushes and clinging upside down, with its long tail held high. Herbivores, their diets include wild or cultivated fruit and even seedlings. They are therefore considered pests by gardeners and farmers. They build nests in bushes and sometimes cannibalize their young if they stray from the nest. They dislike rain and cold, huddling together and sometimes becoming torpid. Their feathers are replaced randomly and have long aftershafts.

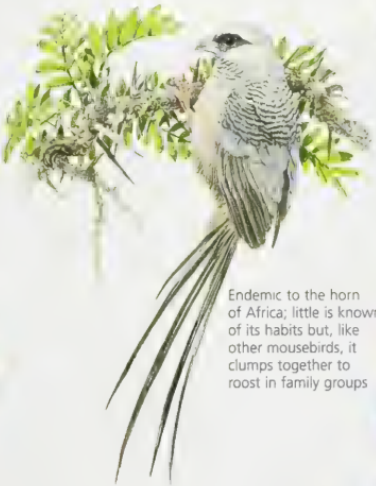
**Only in Africa** Mousebirds live in a wide range of African habitats, from almost-dry bushland to the edge of forests, south of the Sahara.

**Spread out** Blue-naped mousebirds (*Urocalius macrourus*) (left) demonstrate one of the unusual characteristics of this bird family: a perching style in which the feet are kept almost level with the shoulders.

**This way or that** Mousebirds have unique feet with two reversible outer toes that can point either forward or backward. Because of this, they can imitate the toe arrangements of all other birds. It helps when scrambling and clinging to vegetation.

***All points of the compass*** *The center toes of mousebirds can point in any direction.*

White-headed mousebird
*Colius leucocephalus*



Endemic to the horn of Africa; little is known of its habits but, like other mousebirds, it clumps together to roost in family groups

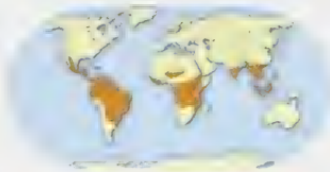
Speckled mousebird
*Colius striatus*

Ranges over tropical and eastern Africa; monogamous, but other members of each communal group may help in the rearing of young

# TROGONS

CLASS Aves
ORDERS 1
FAMILIES 1
GENERA 6
SPECIES 39

The best known of these brilliantly colored birds is the resplendent quetzal, the national bird of Guatemala, which was considered divine by the Aztecs. Female trogons are generally duller than males, and the Asian species are not as colorful. Trogons are secretive and territorial, perching while they scan for food. They eat insects and small lizards; some species also eat fruit. Males sometimes stage displays that include chases through the trees.



**Pan-tropical beauties** Trogons are forest dwellers. They can be found in the tropical regions of several continents. Arboreal birds, they live in rain forests and monsoon scrubs

**Sticking out** A male resplendent quetzal (above) peers from its nest in a tree hollow Trogons nest in such hollows or excavate nest holes in dead trees. Although male trogons may group to display to several females, they are monogamous and share nesting duties

# KINGFISHERS AND ALLIES

**Waters and woods** Kingfishers and their relatives can be found in a variety of aquatic and wooded environments around the world. The regions with the most species are Africa and Southeast Asia. Eastern kookaburras are found only in Australasia. "Non-fishing" kingfishers then inhabit rain forests and woodlands.

[illegible]

Kingfishers are linked to rollers, motmots, bee-eaters, rollers, hornbills, the hoopoe, and wood-hoopoes due to certain anatomical and behavioral similarities. All of these birds have small feet with three fused forward toes. They also have similarities in their fat bones and egg proteins. Many species have brilliantly colored plumages, and all nest in holes that they dig in soil or in rotting trees with their bills. Kingfishers are recognized by their short legs and their large, robust, long, and straight bills, which typically have sharply pointed or slightly hooked tips. The former are best suited for perching or and grasping fishes and other prey, and the latter for holding and crushing prey.

**Bee-eaters's feeders** [illegible]

## DIFFERENT HABITS

Most kingfisher species are generalized predators that eat a variety of terrestrial and aquatic invertebrates and vertebrates. Their typical foraging technique involves sitting quietly on a perch from which they can quickly survey their surroundings. Spotting prey, they then swoop on their prey and seize it in their bills, then returning to their to the perch, they immobilize it by striking it repeatedly against a branch before eating it.

Some kingfishers, however, have markedly different diets and exhibit a variety of foraging techniques, such as hovering and plunge dives or search of insectivores.

Todies—very small, stocky birds with flattened bills—capture insect prey from the undersides of leaves. They also catch insects in flight.

Bee-eaters hot foraging insects, mostrating and hawking off the wing before returning to their perch.

[illegible]

[illegible]

Green kingfisher
*Chloroceryle americana*

African pygmy-kingfisher
*Ceyx pictus*

Banded kingfisher
*Lacedo pulchella*

Common kingfisher
*Alcedo atthis*

Lilac-cheeked kingfisher
*Cittura cyanotis*

Hook-billed kingfisher
*Melidora macrorrhina*

White-throated kingfisher
*Halcyon smyrnensis*

Laughing kookaburra
*Dacelo novaeguineae*

## FACT FILE

**Common kingfisher** The vivid upper parts can appear either cobalt blue or emerald green, depending on the temperature of the light. It flies from over the water, and nests inside burrows on river banks.

- Up to 6.5 in (16 cm)
- 1–10
- Least Concern
- Partial migrant
- Common

Europe, Africa, Asia, Australia

**Laughing kookaburra** This bird is unmistakable due to sounds like laughter. It hears in hollow trunks or holes in trees, is sometimes in family-our family groups. The young remain in the nest for over a month.

- Up to 17 in (43 cm)
- 1–4
- Least Concern
- Resident
- Common

E. novaeguineae, D. leachii, D. novaeguineae, D. tyro

## DIVING ACTION

Young kingfishers are taught to fish by their parents, who drop dead fish into the water for the young to retrieve. When the young have mastered the technique and can catch their own food, they are chased away from the territory by the parents.

Kingfishers typically wait for prey either while sitting on a tree, wire or other high perch overlooking the water, or while hovering overhead. Some kingfishers have outstanding fisheyes that even than eliminate water refraction so that they can better see their prey beneath the surface. Their eyes are protected by a membrane. They snap their bills only when they feel the fish in their mandibles.

**A trained eye**

[illegible]

## FACT FILE

**Cuban tody** All the species of tody are confined to the West Indies. They look quite similar, heard from the [illegible] in a duet in the course of an aerial flight. [illegible] a burrow.

[illegible]

**European bee-eater** This bird, [illegible] and flood [illegible] its bill and dipped off the long barbs earlier. It nests in [illegible] tunnels that pairs dig with their beaks and legs.

[illegible]

**Dollarbird** This bird gets its name from [illegible] patches of silvery white on its wings. When the bird flies, these patches resemble American silver dollar coins. It [illegible] insects caught on the wing.

[illegible]

**Carmine bee-eater** The two regional populations of this species undergo [illegible] migrations each year. They live in large colonies of up to 1,000 pairs. They [illegible] in the banks of large rivers, [illegible] to catch insects.

[illegible]

## CONSERVATION WATCH

**Hotspots of danger** The world's five ground-rollers live in Madagascar, three of them are listed as vulnerable by IUCN. Of the 21 endangered and vulnerable species of kingfishers and allies, [illegible] live in the Philippines, including the critically endangered [illegible] montani and [illegible] waldeni. [illegible] four of the eight threatened kingfishers also occur there. [illegible]

Rufous-headed ground-roller
*Atelornis crossleyi*

Long-tailed ground-roller
*Uratelornis chimaera*

Common hoopoe
*Upupa epops*

Cuckoo-roller
*Leptosomus discolor*

♂

Cuckoo-rollers give loud whistling and cackling cries as they glide over Madagascan forests; the calls are among the most characteristic for the island

Green wood-hoopoe
*Phoeniculus purpureus*

Red-billed hornbill
*Tockus erythrorhynchus*

♂

Northern ground-hornbill
*Bucorvus abyssinicus*

Feeds on the ground, walking about in pairs or small groups, picking up a range of vertebrate and invertebrate prey

♂

Great hornbill
*Buceros bicornis*

Monogamous, territorial birds that nest in big hollows in tall rain-forest trees; the male seals the female in to incubate by blocking up the entrance hole with mud, then feeds his mate and chicks through a small hole in the entrance for the period of incubation and rearing, up to about 100 days

## FACT FILE

**Common hoopoe** The sole member of its family, the hoopoe probes with its long bill into soft earth, debris, or dung to look for insects and larvae. It reuses some nest sites from year to year.

- Up to 12½ in (32 cm)
- 4–8
- Sexes alike
- Partial migrant
- Common

N, E, & S Eurasia, sub-Saharan Africa

**Cuckoo roller** This active, noisy, largely arboreal bird is often seen in pairs. It catches large insects and lizards among branches and foliage, and sometimes circles above the canopy.

- Up to 20 in (50 cm)
- 4–9
- Sexes differ
- Sedentary
- Locally common

Madagascar

**Great hornbill** This bird has a casque on the upper half of its bill. Males and females have different coloration in their bills, their eyes, and in the rings around their eyes. They eat fruit, invertebrates, and small vertebrates.

- Up to 3½ ft (1.1 m)
- 1–4
- Sexes alike
- Sedentary
- Rare

N India & Himalayas to S E Asia, Sumatra

## CAVITY NESTS

The hoopoe (below) nests in cavities. Some sites are reused. The young are initially cared for by the female and later by both parents. In most species of the related hornbills, which also nest in natural cavities, the female closes the entrance hole and remains with the chicks for months. The male feeds the entire family through a small hole.

# NESTS

In most birds, as soon as a breeding pair forms, one or both adults will begin to build a nest. The structure is used to cradle the eggs, house the developing chicks, and help keep them safe from predators. Selecting the nest site and building the nest are tasks that may be performed by either sex, alone or as a pair. Each adult's involvement, the choice of site, technique and building materials, and the energy that is invested in nest-building are characteristics that vary among species. The widely recognized cup-shaped nest is typically built using twigs and other plant matter that is threaded or twisted together to prevent the structure from falling apart. Other nest types include stick platforms, excavated tree hollows, scrapes or burrows in the ground, mud "ovens," and rotting mounds of vegetation. Some birds reuse the nests of others. A few species build nests for purposes other than to house chicks, or else build no nests at all. Some use nests at non-breeding times of the year, for sleeping or for shelter; such dormitory nests rarely house their young. Bowerbird males build elaborate nests, but only to attract females, who, after mating, then go off alone to build the actual nest that will house eggs and young. A few birds build no nests: some penguins, for example, simply incubate their eggs and hold their developing young on top of their feet.

**A ready-made home** The eastern screech owl (*Otus asio*) (above) makes its nest in available tree hollows. Owls also raise their young in holes in cliffs or in old buildings, and they sometimes reuse the stick nests of crows or hawks. Other birds such as kingfishers also nest in cavities, which they dig in riverbanks. Some birds have been known to use old rabbit holes.

**A prickly abode** The cactus wren (*Campylorhynchus brunneicapillus*) (right) uses sticks to make a somewhat bulky, domed nest, which it prefers to place among the spines of a cactus. Wrens also build nests for sleeping.

**Easy access** A red-throated loon (*Gavia* [illegible] above) joins a chick in a nest built [illegible] a lake in Alaska. Loon nests [illegible] thing more than shallow [illegible] gy ground, although some [illegible] water weeds. They are [illegible] small islands

**A nest with a view** European white storks (*Ciconia ciconia*) (below) often nest on man-made structures, in this case the ruins of a church in Algeria. These birds, which mate for life, pile branches into massive nests that they use for many years.

**One among many** A sociable weaver (*Philetairus socius*) (above) peeks out of its hole in a communal nest. Weavers are renowned for building intricately woven grass nests. They push and pull material into loops and knots in a technique that is similar to basket weaving.

**A multi-family dwelling** The very large, communal nests (right) of sociable weavers can weigh more than 1 ton (1 tonne) and house hundreds of birds. A small chamber houses each pair. Nests are used for years.

**On the rocks** A large colony of king cormorants (*Phalacrocorax albiventer*) (left) sit on their nests in the Falkland Islands. This species of cormorant builds its nest on cliff-top slopes using mud and vegetation. Other species use seaweed, guano, or old bones. Those cormorants that nest in trees use twigs

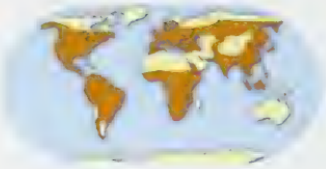
**Home in a cup** A vireo (below) sits on her nest in an oak tree. The cup shape is ideal for preventing eggs from rolling out. Fragments of spider web may serve to bind, and lichen on the outside may serve as camouflage

***Careful construction*** *Vireos (right) build cup-shaped nests using fine grasses, spiders' web and strips of bark. They suspend them from forks in branches in the mid- to upper levels of trees*

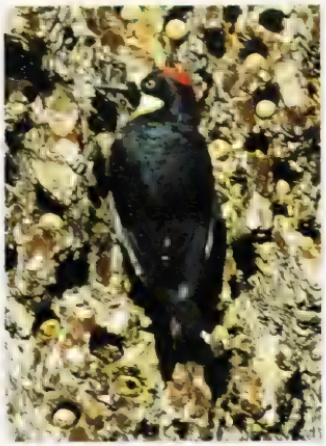
# WOODPECKERS AND ALLIES

CLASS Aves
ORDERS 1
FAMILIES 5
GENERA 68
SPECIES 398

These six families of birds—woodpeckers, honeyguides, jacamars, puffbirds, barbets, and toucans—look different but share certain anatomical features, such as zygodactyl feet, with two toes in front and two at the back. They also generally lack down feathers and lay white eggs. Most species are colorful; some are even gaudy. They are primarily tropical birds that nest in cavities in trees, in termite mounds, or in the ground. Woodpeckers and barbets typically excavate their own cavities; after they are abandoned, the holes are often used by other species. Woodpeckers sometimes live within sight of large cities and are frequent visitors to bird-feeding stations.



**Wide ranges** Woodpeckers live in forests; toucans, jacamars, and puffbirds in the New World tropics. Honeyguides are mainly African. Barbets are more widely dispersed



**Hanging on** An acorn woodpecker (*Melanerpes formicivorus*) (far left) clings to a pine tree studded with acorns. These birds store their acorns in holes in special storage trees, which they fiercely defend. They then rely on these food stores during the lean winter months. They live in oak and mixed oak woodland in western America and may be monogamous or polygamous, depending on the area

**Sticking out** A toco toucan (*Rhamphastotos toco*) (left) eats a goiaba fruit. These odd-looking birds have frilled tongues and often serrated bills, which they use to adroitly pick fruits from trees. They also sometimes prey on untended eggs or nestlings. They are the only toucans that live outside rain forest, frequenting riverside growth and savannas

## SPECIALIZED FEATURES

Woodpeckers are often heard before they are seen. They use their strong, tapering, often chisel-tipped bills to peck at the bark of trees, probing for insects. Bony, muscle-cushioned skulls help protect them from the impact. They use their strong, long-clawed toes to grip the bark and their straightened tail feathers to prop themselves against the trees. Most of them hop rather than walk.

Despite their large, gaudy-colored bills, which can be up to a third or more of their body length, toucans are often surprisingly inconspicuous as they perch on branches amid foliage. They feed mainly on fruit, as do the brightly colored and patterned barbets, which have relatively stout, sometimes notched bills.

Jacamars and puffbirds eat insects, flying forth from perches to catch them. They nest in tunnels that they excavate; some species cover the entrance with a pile of sticks. The typically inconspicuous and inactive puffbirds are named for their unusually loose, fluffy plumage.

Honeyguides also eat insects, as well as wax from beehives. Their name comes from the fact that one species leads humans to beehives.

Some species within these families are solitary; others, such as the nunbirds and puffbirds, are social and even breed cooperatively. Some African barbets nest in pair groups of 100 or more birds, all residing in one dead tree. The greater honeyguide is a brood parasite, laying one egg in the nest of each host bird.

Barbets tend to be highly vocal; some are called "brain-fever birds" because of their unceasing, monotonous calls. Uniquely among birds, woodpeckers have developed instrumental drumming on wood. The tone and pattern are species-specific.

Yellow-rumped honeyguide
*Indicator xanthonotus*

Greater honeyguide
*Indicator indicator*

This Himalayan honeyguide is one of only two species of the group to occur outside Africa

Lesser honeyguide
*Indicator minor*

Honeyguides are rather small gray-green birds with distinctive white flashes at the sides of the tail; wax from insects or their nests is their staple diet

Black-necked aracari
*Pteroglossus aracari*

Curl-crested aracari
*Pteroglossus beauharnaesii*

Emerald toucanet
*Aulacorhynchus prasinus*

Toco toucan
*Ramphastos toco*

Distinctively striped bill, this species lives in montane rain forest in the northern Andes

Gray-breasted mountain-toucan
*Andigena hypoglauca*

Zygodactyl toes with two forward and two back, an arrangement better fitted for clasping perches than for running

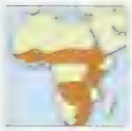
Channel-billed toucan
*Ramphastos vitellinus*

Moderately alternated tail that is often cocked temporarily at perches or during vocalizations

Identified by its broad crimson breast band and dark bill. It lives in the lowland rain forests of tropical South America. It eats palm nuts, fruits, and insects and drinks from bromeliads or by holding the bill open in rain

## FACT FILE

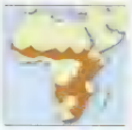
**Greater honeyguide** This bird is known for leading humans to the hives of wild honeybees. The humans harvest the comb and leave the remains for the bird, which is particularly fond of the wax.



Up to 8 in (20 cm)
Sets of up to 5
Sexes alike
Sedentary
Common

Sub-Saharan Africa excl. Congo basin & S.W.

**Lesser honeyguide** Like other honeyguides, the lesser honeyguide is a brood parasite. Newly hatched young use a hook on their bills to kill the host's chicks and push them out of the nest or they break the eggs before hatching.



Up to 6½ in (16 cm)
Sets of 2–4
Sexes alike
Sedentary
Locally common

Sub-Saharan Africa excl. Congo basin & S.W.

**Emerald toucanet** The male and female of this small green toucan are alike in color but differ in size, the male being slightly larger. The emerald toucanet sometimes appropriates the previously used nesting holes of other species, or excavates its own.

Up to 14½ in (37 cm)
1–5
Sexes alike
Sedentary
Locally common

Mexico, S. Central & N.W. South America

**Toco toucan** The toco toucan lives in family groups or flocks. It nests in holes in trees and often pecks noisily at tree branches. Two birds will sometimes clash their bills together.

Up to 24 in (60 cm)
2–4
Sexes alike
Sedentary
Locally common

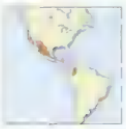
N.E. South America

## CONSERVATION WATCH

**Woodpecker wake** The IUCN lists 14 species of woodpeckers and their allies as threatened: 7 vulnerable, 4 endangered, and 3 critical. The critically endangered species are all woodpeckers, and although the ivory-billed may be extinct, it had disappeared from southeast mainland United States by the 1970s, but persisted in Cuba until the 1990s.

## FACT FILE

**Acorn woodpecker** This unmistakable bird is common in oak woods. It is a social bird that can be heard making chattering and rhythmic laughing calls. The birds eat insects (pried from tree trunks or caught in flight) and acorns.



Up to 9 in (23 cm)
4–6
Sexes alike
Sedentary
Common

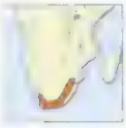
N. North to N.W. South America

**Yellow-bellied sapsucker** The male and female of this species have different colored throat patches. At nesting grounds, the bird makes distinctive drumming sounds, with alternating rapid and slow thumps.

Up to 8 in (21 cm)
4–7
Sexes differ
Migrant
Common

C. N. to S.E. North America, Central America

**Ground woodpecker** This species feeds almost entirely on the ground. It is specialized to eat ants by probing crannies and digging its bill into ants' nests, head down. It also nests on the ground, in 3¼ ft (1 m) long burrows, dug mostly by the male.

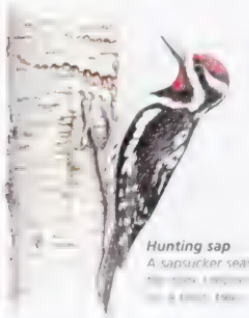


Up to 12 in (30 cm)
2–5
Sexes alike
Sedentary
Locally common

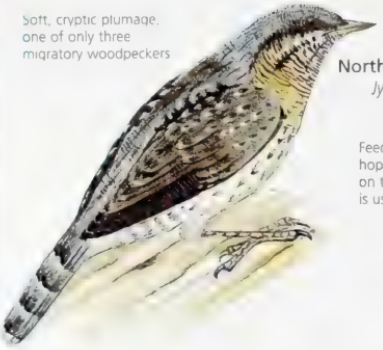
Cape Province to Transvaal & Natal (Africa)

### SUCKING SAP

The yellow-bellied sapsucker is one of several North American woodpeckers that peck rows of holes in the trunks of certain trees. They feed on the sap that accumulates in the holes, as well as on the insects that are attracted to the sap. These sap wells, dug in late summer and fall, are also exploited by other birds and mammals.



***Hunting sap*** A sapsucker searches



Soft, cryptic plumage, one of only three migratory woodpeckers

**Northern wryneck**
*Jynx torquilla*

Feeds mostly on ants, hopping around mainly on the ground; curved bill is used to open anthills

**Acorn woodpecker**
*Melanerpes formicivorus*

Acorn woodpeckers are well known for their habit of storing nuts in holes in trees for winter

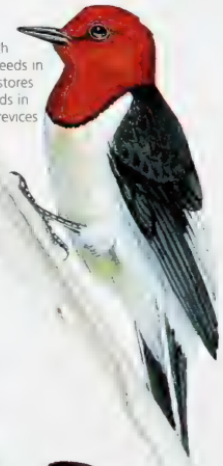
A white rump helps to identify this species

**Gray woodpecker**
*Dendropicos goertae*

Feeds by pecking on the middle branches of trees on ants, termites, and other insects

**Yellow-bellied sapsucker**
*Sphyrapicus varius*

**Red-headed woodpecker**
*Melanerpes erythrocephalus*



Feeds on both insects and seeds in forests, and stores nuts and seeds in cracks and crevices for winter

**Golden-tailed woodpecker**
*Campethera abingoni*

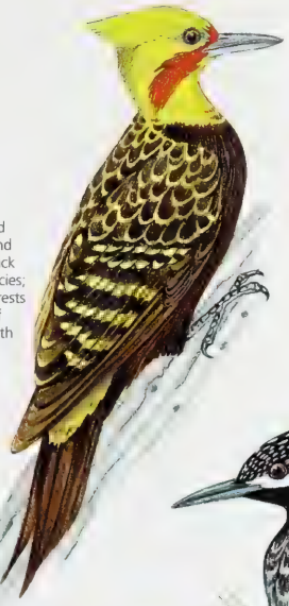
Brown-capped woodpeckers live in woodlands and forage on trees for ants and other insects

**Ground woodpecker**
*Geocolaptes olivaceus*

**Brown-capped woodpecker**
*Dendrocopos moluccensis*

Rufous woodpecker
*Celeus brachyurus*

Yellow head, red cheek splash, and gold mottled back identify this species; it lives in the forests and savannas of central east South America



Blond-crested woodpecker
*Celeus flavescens*

Black woodpecker
*Dryocopus martius*

Pileated woodpecker
*Dryocopus pileatus*

This Indian species lives in dry to moist woodlands; it forages at all levels in trees on ants and other insects

Black-rumped woodpecker
*Dinopium benghalense*

A stiffened, tapered tail helps to prop woodpeckers as they clasp upright trunks and branches in their feeding

Greater yellow-naped woodpecker
*Picus flavinucha*

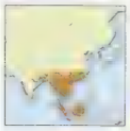
Green woodpecker
*Picus viridis*

This widespread Eurasian woodpecker has similar habits to the European green woodpecker

Gray-headed woodpecker
*Picus canus*

## FACT FILE

**Rufous woodpecker** This bird appears frequently in gardens. It has the unusual habit of building its nest by digging a burrow in the middle of a tree ant nest, thus giving it a ready food supply at its doorstep.



Up to 10 in (25 cm)
2–3
Sexes alike
Sedentary
Common

S. & S.E. Asia to Borneo & Sumatra

**Pileated woodpecker** This adaptable, widespread large bird can even be seen within sight of skyscrapers. It eats primarily ants, which it extracts from rotting trees and fallen logs, using its frilled, sticky tongue.

Up to 18 in (46 cm)
2–6
Sexes differ
Sedentary
Rare

C.W. & E. North America

**Green woodpecker** This bird has a distinctive flight pattern, alternating three or four wingbeats with undulations with wings closed. It sometimes lays up to 11 eggs.

Up to 13 in (33 cm)
4–8
Sexes differ
Sedentary
Common

Europe to trans-Caucasia, N.W. Africa

***Grounded***
*The European green woodpecker feeds mainly on the ground*

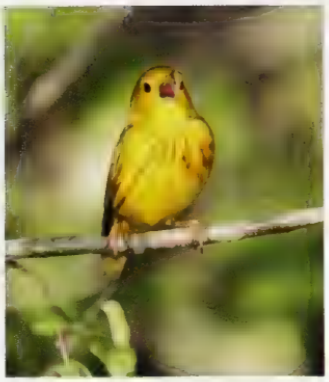
## TONGUE AND GROOVE

The hairy woodpecker is typical of the family in that it bores a hole in the trunk of a tree and uses its long bill to extract insects from the interior. Woodpeckers have extremely long tongues that can be extended well beyond the end of the bill. The muscled [illegible] the tongue loops over [illegible] and behind the [illegible]

# PASSERINES

CLASS Aves
ORDER Passeriformes
FAMILIES 96
GENERA 1,318
SPECIES 5,754

Passeriformes is the largest order of birds by far, encompassing more than 5,700 species. At the same time, this order includes a disproportionately small percentage of bird families, meaning that each passerine family has a relatively high number of species. These two facts together attest to the great evolutionary success of the passerines. Relative newcomers—they are believed to have evolved about 75 million years ago on the southern super-continent Gondwana—they have proven themselves remarkably adaptable, having spread to every continent except Antarctica. Sometimes known as perching birds or songbirds, they are distinguished by their distinctive palates, voice box, and feet.



**Small but powerful singer** The yellow warbler (*Dendroica petechia*) (above) sings from a branch. Its bright song has been phrased as "sweet sweet sweet, I'm so sweet." The warblers are members of the suborder Oscines, whose members have the most elaborately muscled voice boxes and are therefore the best singers

## SKILLED VOCALIZERS

The passerines are typically small or medium-sized birds, which nevertheless vary greatly in shape, size, and plumage colors (the last ranges from very drab to brilliant).

Their feet, unlike those of other bird orders, have four toes, each of which joins the leg at the same level; three of the toes are directed forward, whereas the innermost one is directed backward. This foot structure and the flexibility of the toes are ideally suited to grasping perches, whether they be trees, shrubs, or even blades of grass.

Most passerines have wings that taper to a point at the outer tip. This shape makes them well suited for rapid take-offs and good in-air maneuverability, which is useful for catching prey and also for avoiding predators. They are less capable of sustaining high flight speeds.

Most passerines are songbirds, or oscines. Unlike mammals, which produce sound in their larynx, birds make sound in a voice box known as a syrinx. This unique structure at the base of the windpipe, or trachea, consists of two chambers and relies on about half a dozen pairs of muscles to control the tension of its three elastic, vibrating membranes. The bird's trachea, interclavicular air sac and mouth modify the sound that is produced. The two chambers allow the bird effectively to sing a duet by itself.

One large group of passerines includes birds with poorly muscled voice boxes and simple, stereotyped songs, among them the pittas and broadbills of the Old World tropics, and the ovenbirds, antbirds, tyrant flycatchers, and cotingas of Central and South America.

### CONSERVATION WATCH

The 1,999 species of Passeriformes on the IUCN Red List are categorized as follows:

- [illegible] Extinct
- [illegible] Critically endangered
- [illegible] Endangered
- [illegible] Vulnerable
- [illegible] Conservation dependent
- [illegible] Near threatened
- [illegible] Data deficient

**On the hunt** A blue tit (*Parus caeruleus*) (above) hovers beside an oak tree as it [illegible] for insects. Hardy and [illegible] they vary their diet with the seasons, eating seeds during winter when other prey is harder to find. In spring they [illegible] for breeding.

**A good match** The iiwi (*Vestiaria coccinea*) [illegible]

**Mealtime** A noisy pitta (*Pitta versicolor*) (left), an Australian native, sits on a perch after a successful attempt to catch some worms. Pittas are terrestrial forest inhabitants and are among the most colorful of birds. Some other insect-eating passerines hunt their prey in flight.

**Hungry mouths to feed** A marsh wren (*Cistothorus palustris*) (right) feeds its chicks at a nest on Long Island, in New York, United States. All passerine young are altricial, meaning they are born naked, helpless, and blind. The nestlings gape to indicate that they want to be fed. Parents have such a strong feeding instinct that they occasionally even feed other species.

In the past, many families in this order were grouped together due to morphological similarities. These were in many cases later attributed to convergent evolution rather than very similar genetics; for example, the wrens of Australia are not close relatives of the wrens that live in the Northern Hemisphere.

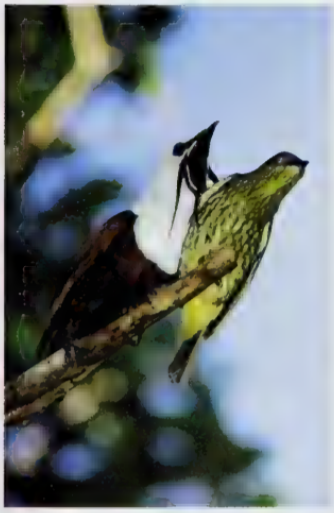
Most passerines eat plants or insects or both. During each breeding season, adults and young alike may consume more protein.

Most of the birds in this order are monogamous, and both parents help rear the young, although the female tends to do more brooding.

**Wading in** An American dipper (*Cinclus mexicanus*) (left) stands in a waterhole. The five species of dippers, which do not have webbed feet but use their wings to hunt for insects underwater, are the only truly aquatic birds in the passerine order.

**Small passengers** A group of yellow-billed oxpeckers (*Buphagus africanus*) (below) sits on the back of a buffalo in Africa. Also known as tickbirds, they can be seen riding on different species of large mammals, pecking for ticks on their hides Some related starlings eat parasites on livestock, but also swoop down to eat insects disturbed by the grazers.

**Displaying** A male three-wattled bellbird (*Procnias tricarunculatus*) (below) gets close to a female in a cloud forest in Costa Rica. Bellbirds are among the world's loudest birds. During the breeding season, the male stands on a display perch high in a tree canopy and makes a sound akin to a sledgehammer hitting an anvil, which can be heard up to ½ mile (1 km) away.



## FACT FILE

**Antbirds and allies** These diverse passerine birds inhabit woodlands and thickets in South and Central America. Many follow swarms of army ants, eating the insects killed as the ants move. Sometimes these encounters are composed of birds of several species.

**Family Formicariidae** Antbirds get their name from some species' habit of clinging to vertical stems above ant swarms. Some glean squirrels as they forage, generally according to season of prey. Their songs are usually complex.

Genera 7
Species 60

Lowlands to mountains, South America

**Family Furnariidae** The rufous hornero and some of its relatives build mud nests that resemble medieval clay ovens, hence the name ovenbirds. Such nests protect the young from sun, wind, and predators. Ovenbirds are adapted for moving in narrow places.

*White-faced antbird*
*Thamnomanes ardesiacus*, including swarm-ant army ants, ready to scurry on anything they pounce

Genera 55
Species 236

Lowlands, mountains, America

**Family Dendrocolaptidae** Woodcreepers are sometimes confused with woodhewers due to their common habit of using their bills to pierce themselves identifying traits. Woodcreepers however have distinctive feathers and are distinguished by their patterned plumage.

Genera 11
Species 51

Lowlands, mountains, America

## CONSERVATION WATCH

**Declining forest dweller** One of two members of the Dendrocolaptidae family listed on the IUCN Red List, the (rufous-tailed) woodcreeper (*Dendrocolaptes hoffmannsi*) lives in the Dry Diagonal of eastern Brazil. It is numerous because mature trees are attractive and being harvested for timber, or fuel (charcoal industry).

## FACT FILE

**Manakins and cotingas** Manakins, of the family Pipridae, and cotingas, of the family Cotingidae, share a similar diet and distribution. The high degree of color difference in the plumage of the sexes in both families suggests that they also share a complex social behavior

**Family Cotingidae** These fruit-eating birds are typically found in the upper portions of the forest canopies in Central and South America. They also congregate in low densities and are therefore poorly known. In most species, only the males are brightly colored; the females are plain and dowdy. The family's complex social behavior is typified by the Guianan cock-of-the-rock, the males of which congregate at leks to display like cocks After mating, females leave to build nests in rock crevices.

Genera 33
Species 96
Mexico to South America

**Family Pipridae** Manakins are small, brightly colored fruit-eaters with short tails and short, wide bills. They live in lowland forests of Central and South America. Their complex social behavior includes elaborate courtship rituals in which males congregate at leks, where they prepare dance arenas or perches

***Ritual brushing***
*During courtship, the male wire-tailed manakin (right) rapidly brushes the female's throat with the wire-like tips of his tail feathers*

Genera 13
Species 48
S. Mexico to subtropical South America

## CONSERVATION WATCH

**Tiny population** There are believed to be fewer than 50 individuals remaining of the kinglet calyptura (*Calyptura cristata*), a very small, yellowish cotinga that lives north of Rio de Janeiro, Brazil. This qualifies the species as critically endangered. This altitudinal migrant has been affected by deforestation

## FACT FILE

**Tyrant flycatchers** These birds of the Americas are addressed in the Old World flycatchers, although they mostly prefer earthbound habitats, some specialists hovering over flowers, others are ground feeders.

**Family Tyrannidae** This largest of the passerine families includes five tyrant flycatchers as well as pewees, tirranos, elaenias, shrikes, and tyrannulets. The sexes usually look alike, with green, brown, yellow and white plumage.

Genera 98
Species 416

South America, Mexico, Central America

## DIET SPECIALIZATION

Different species within the Tyrannidae family exploit very particular niches within their environments, allowing dozens of species to coexist in some areas. In some cases this is due to different food preferences, such as for fruit as opposed to insects. But in the feeding of prey, it can be attributed to exploit different compositions of prey, use habitat, vegetation type, hunting position, and approach technique.

**Ground feeders** The world's ground-feeding tyrants, which include some of the smallest species in terms of bill, long legs, and terrestrial, are mostly plumage patterns.

**Foliage gleaners** Specialists in forest canopies, with bill as a strong specialization in a full-grown foraging, they hopping or jumping, hanging, or even hanging upside down.

## CONSERVATION WATCH

**Fragmented range** The known range of a relatively unnoticed species that belongs to the Tyrannidae family, the Bahamian flycatcher (*Myiarchus sagrae*), little is known within a protected area in Haiti. But the very small, severely fragmented nature of its range that leaves it be listed as vulnerable.

# COOPERATIVE BREEDING

About 3 percent of all bird species are classified as cooperative breeders, meaning that additional birds—either juveniles or adults—help the parents raise their young. Recent studies have shown that this phenomenon is more prevalent among passerines than was previously thought. There are two forms of cooperative breeding. One involves non-breeding birds helping parents protect and rear their nestlings. The other, called communal breeding, involves some shared parentage (whether shared maternity, paternity, or both) of the offspring that a group of adults are raising together.

**Group effort** White-winged choughs (*Corcorax melanorhamphos*, above) are very sociable birds that live in flocks—typically a breeding pair and offspring from previous years—all year round. The young birds help the parents with nest-building, incubation, and feeding duties. The feeding instinct of parental birds is very strong, so they may respond to feeding calls and gaping mouths of nestlings that belong to other birds even if they are of different species.

***Staying behind*** *Like many other Australian birds, juvenile superb fairy-wrens (left and right) from an earlier brood frequently remain with their parents to help raise their younger siblings. This helps increase the chances of similar genes surviving.*

***Tidying up*** *An immature (or eclipse) male superb fairy-wren (right) removes a fecal sac from the nest. Helpers carry out various chores, including tidying the nest, procuring food, and protecting the nestlings from predators.*

***A lighter load*** *The mother (left) brings food to her nestlings; her workload is considerably eased by the presence of her helpers. Studies have shown that chicks raised in communal settings are fed more insects per hour than those raised in a nuclear family setting.*

**A group effort** The superb fairy-wren (*Malurus cyaneus*) (right) is one of the many communally breeding species of passerines. It is common in southeastern Australia, including in suburban gardens. Why cooperative breeding evolved in some species of birds and not in others is still something of a mystery, especially in light of the patchy distribution of the phenomenon among genetically related types of birds. Ornithologists believe it is probably related to a combination of factors, including environmental constraints (with respect to the availability of unoccupied breeding territories or sexually mature mates) and life-history traits, such as mortality rates and dispersal tendencies. Helpers may include birds whose own attempts at nesting have failed that season.

## FACT FILE

**Tropical and Southern Hemisphere families** The greatest concentration of bird species occurs in those parts of the world with the greatest degree of biodiversity in general, which gives birds more ecological niches to exploit. These areas tend to be concentrated in the tropics. The generally milder climes of the Southern Hemisphere also support many bird species. Many birds in these regions are brightly colored and often green, like surrounding foliage.

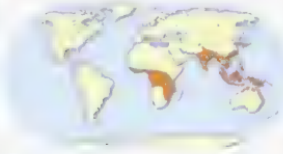
**Family Eurylaimidae** Known as broadbills, the members of this family are stout birds with broad heads; broad, flattened bills; and short legs. They have striking plumage and, in some cases, brilliant red, green, or yellow eyes. Most species eat insects, as well as small lizards, frogs, and fruit.

Genera 9
Species 14

Tropical Africa, S.E. Asia, Gr. Sundas, S. Philippines

**Family Pittidae** Pittas are thrush-sized, insect-eating birds with short tails. They are brilliantly colored forest-dwellers that prefer to hop or run rather than fly. Their large nests, built on the ground or in low vegetation, resemble piles of plant debris. All give loud, melodious double whistles.

Genera 1
Species 30



E. Africa, S.E. Asia to N. & E. Australia, Melanesia

***Stealthy bird*** *The banded pitta, though colorful, is surprisingly inconspicuous on the forest floor. It feeds quietly and seldom calls.*

## CONSERVATION WATCH

**Dwindling mangroves** The IUCN lists 13 members of the Pittidae family, including the mangrove pitta (*Pitta megarhyncha*). It is considered near threatened because its mangrove habitat in southern Asia is being cleared for construction materials, fuel, and charcoal production.

Long, curved bill adapted for nectar feeding

**Scarlet-chested sunbird**
*Chalcomitra senegalensis,*
family Nectariniidae

**Cape sugarbird**
*Promerops cafer,*
family Promeropidae

**Brown-throated sunbird**
*Anthreptes malacensis,*
family Nectariniidae

Sugarbirds have long, plumed tails

**Stripe-headed creeper**
*Rhabdornis mystacalis,*
family Rhabdornithidae

**Red-browed treecreeper**
*Climacteris erythrops,*
family Climacteridae

**Orange-bellied flowerpecker**
*Dicaeum trigonostigma,*
family Dicaeidae

Treecreeper's toes are fused at base to work like calipers

**Crimson-breasted flowerpecker**
*Prionochilus percussus,*
family Dicaeidae

Fine, toothed bill for skinning fruit

**Mistletoebird**
*Dicaeum hirundinaceum,*
family Dicaeidae

**Spotted pardalote**
*Pardalotus punctatus,*
family Pardalotidae

## FACT FILE

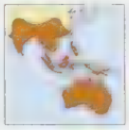
**Sunbirds, tree-creepers, and flowerpeckers** This group of small, tree-dwelling birds is found throughout the Old World tropics and south temperate zones. Families native to Australasia are the most distinctive

**Family Nectariniidae** Sunbirds are strongly associated with flowers. They are lively, colorful birds with long, slender, decurved, and finely serrated bills. Their tubular, deeply cleft tongues are adapted for sucking nectar

**Genera** 16
**Species** 127

Sub-Saharan Africa, S. Asia to Melanesia & N.E. Australia

**Family Dicaeidae** The flowerpeckers are dumpy birds with pointed wings, stubby tails, and short, conical bills. Their cleft tongues are adapted for feeding on nectar as well as fruit



**Genera** 2
**Species** 44

India, S.E. Asia & its archipelagos to Melanesia & Australia

**Family Climacteridae** This small family of bark-climbing birds known as tree-creepers is found only in Australia and New Guinea. They have slender bills, short, square tails, and strong legs

**Genera** 2
**Species** 7

Mainland Australia excl deserts, New Guinea

**Family Pardalotidae** These common, multicolored birds closely resemble flowerpeckers in size and proportions They feed almost entirely on larvae, and on an exudate produced by the larvae, of leaf-eating insects in foliage

**Genera**
**Species**

*Cavity dweller*

## FACT FILE

### Honeyeaters and white-eyes

These tree-dwelling birds are found in Africa, Asia, and Australasia. They vary in size from 3 inches to 19 inches (7 to 48 cm). There is much more size variation among honeyeaters than among white-eyes.

**Family Meliphagidae** Honeyeaters, friarbirds, wattlebirds, miners, and honeycreepers have unique tongues that are deeply cleft and fringed at the tip to help the birds collect nectar. Honeyeaters often specialize in certain types of plants, especially eucalypts.

***Sweet meal*** An eastern spinebill hunches its bill to collect nectar.

Genera 44
Species 174

Australia to Melanesia to E. Sundas (western to Wallacea)

**Family Zosteropidae** White-eyes are found in almost every kind of wooded habitat throughout their range, and in suburban parks and gardens. Many species are very similar in appearance. They have olive plumage, slender, pointed bills, and a ring of dense, white feathers around their eyes. They use their brush-tipped tongues to feed on nectar, fruit, and small insects.

Genera 14
Species 95

Tropical Africa, S. to S. Asia, Australasia

## CONSERVATION WATCH

**Island dweller** The mao (*Gymnomyza samoensis*) of Samoa is a large, endangered honeyeater. Slash-and-burn farming techniques and the introduction of non-native trees have threatened its forest habitat. Half a dozen other Pacific island honeyeaters have already extinct.

Asian paradise-flycatcher
*Terpsiphone paradisi,*
family Monarchidae

Chestnut-breasted whiteface
*Aphelocephala pectoralis,*
family Acanthizidae

Crimson chat
*Epthianura tricolor,*
family Meliphagidae

Penduline tit
*Remiz pendulinus,*
family Remizidae

Black-throated tit
*Aegithalos concinnus,*
family Aegithalidae

Penduline tits are found in Eurasia, Africa, and southern North America

Yellow-bellied fantail
*Rhipidura hypoxantha,*
family Rhipiduridae

Crested tit
*Parus cristatus,*
family Paridae

This species gleans over ground and trees in the Australian bush

Gray shrike-thrush
*Colluricincla harmonica,*
family Colluricinclidae

## FACT FILE

**Tits and flycatchers** These small birds feed primarily on insects. A number of them are distinguished by disproportionately long fanned tails

**Family Monarchidae** Known as monarch flycatchers, the members of this family of small songbirds have a predilection for flicking their tails and for sallying for food on the wing They prefer wooded habitats and often forage in mixed-species parties

Genera 15
Species 87

Australia & Melanesia to Oceania, S.E. & S. Asia, & Africa

**Family Rhipiduridae** Fantails get their common name from their habit of fanning or waving their long tails. They also pirouette through the air and appear hyperactive. Their broad bills are surrounded by bristles that aid in catching insect prey

Genera 1
Species 43

Australasia & Melanesia, Oceania, S.E. Asia & India

**Family Paridae** Tits, chickadees, and titmice tend to have black caps, some with crests, and white cheeks. Most are sedentary, forest-dwelling birds that use their short, straight bills to feed on insects and seeds in foliage

***Standing out***
*The colorful great tit inhabits woods, parks, and gardens. It nests in trees and holes, including artificial nesting boxes*

Genera 3
Species 54

## FACT FILE

**Family Sittidae** Nuthatches are found throughout the Northern Hemisphere and spend their whole lives in trees. They climb, clinging upright and upside-down, around the trunk and branches. Species are similar in appearance, but the two families are not closely related. Nuthatches are distinguished by a combination of features, including a pointed bill, short tail, and strong feet.

Eurasian nuthatch

Density: 1
Species: 1

**Family Maluridae** Just like nuthatches, fairy-wrens are not closely related. The fairy-wrens, grasswrens, and emuwrens that make up this family are small birds that pack their tails. They are insectivores, mostly foraging on the ground and in shrubbery.

Density: 1
Species: 28

Standing out

## CONSERVATION WATCH

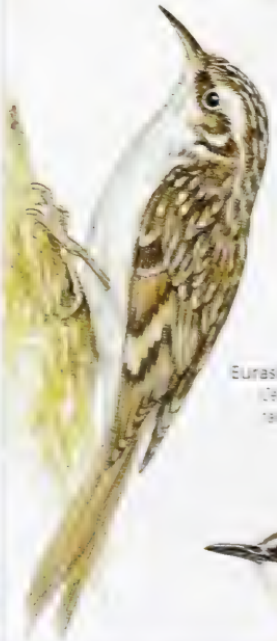
**Sparse sightings** Varied nuthatch, species considered threatened, is confused by others and rarely seen. The endemic Algerian nuthatch has been frequently found in a number of sightings in Algeria, yet it is close to extinction and only a thousand are staying.

Wallcreeper
*Tichodroma muraria*
family Sittidae

Chinspot batis
*Batis molitor*
family Platysteiridae

Males have black breast band

Varied sitella
*Neositta chrysoptera*
family Neosittidae



Eurasian treecreeper
*Certhia familiaris*
family Certhiidae

Variegated fairywren
*Malurus amabilis*
family Maluridae

White-breasted nuthatch
*Sitta carolinensis*
family Sittidae

White-browed scrubwren
family Acanthizidae



Fairy gerygone
*Gerygone palpebrosa*
family Acanthizidae

Yellow-rumped thornbill
family Acanthizidae

Gerygones, scrub-wrens, and thornbills live in Australia and New Guinea

White-browed woodswallow
*Artamus superciliosus,*
family Artamidae

Brubru
*Nilaus afer,*
family Malaconotidae

Red-backed shrike
*Lanius collurio*
family Laniidae

Greater
racket-tailed drongo
*Dicrurus paradiseus,*
family Dicruridae

Eurasian golden oriole
*Oriolus oriolus,*
family Oriolidae

Saddleback
*Philesturnus carunculatus,*
family Callaeatidae

Magpie-lark
*Grallina cyanoleuca,*
family Monarchidae

Tail streamers

This species carols
in duet with others
of its flock

Strong feet adapted
for ground feeding

Australian magpie
*Gymnorhina tibicen,*
family Cracticidae

## FACT FILE

**Shrikes and allies** These families of primarily insect-eating birds can be found throughout the world, although most species are in the Old World.

**Family Artamidae** Wood-swallows have strong, pointed wings, blue-gray bills with black tips, and short legs. They forage in all types of habitats, hawking on the wing. Sociable birds, they perch side by side and preen each other.

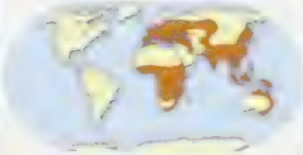
Genera 1
Species 10

Australia & Melanesia to S.E. Asia & India

**Family Oriolidae** Not to be confused with New World orioles, the orioles in this family are found in Old World forests and woodlands. Sturdy birds with often yellow-plumaged males they tend to spend most of their lives high in the treetops, so are often heard but rarely seen.

***An unusual bird*** *The figbird differs from other orioles in several ways. It is gregarious, noisy, and has bare skin around the eye. Its diet consists almost entirely of fruit, primarily figs.*

Genera 2
Species 29



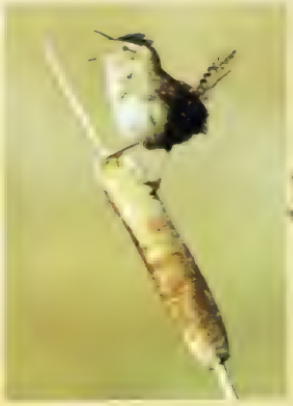
Australia & New Guinea to temperate Eurasia, sub-Saharan Africa

**Family Laniidae** Shrike numbers have been decreasing because pesticides are wiping out the large insects they favor. True shrikes with hooked bills often impale surplus food on thorns. Vangas are related birds that have radiated into a variety of habitats in Madagascar similar to the finches of the Galápagos.

Genera 4
Species 30

North America, [illegible] New Guinea

***Perching*** *The long-tailed shrike [illegible]*



**Singing** A marsh wren (*Cistothorus palustris*) (left) sings while perching on a common cattail in Alberta, Canada. This tiny bird is a perennial singer except during the molting season. The size of song repertoires varies by population.

**Well-researched singers** Zebra finches (*Taeniopygia guttata*), widespread in the dry regions of Australia, are among the best-studied songbirds. To make their songs heard far afield, birds may sing from the highest perches available. This is also one reason that many species prefer to sing in the morning, when the clear air helps carry the sound further. Birds can produce sounds with higher frequencies than the human voice.

***Volume matters*** *Male zebra finches (far left) sing far more loudly when other birds are present, in order to prompt females (left) to respond to their advances and to ward off other males.*

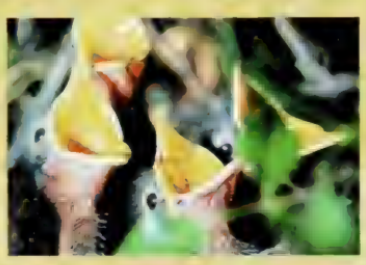
# SONG

Bird songs have inspired musicians, poets, and other artists through the ages. The syrinx, the resonating chamber in which bird sounds are produced, is a complex structure that is best developed in the group of passerines known as oscines. Different species can be distinguished by their songs, although some birds, such as the village indigobird, are very skilled at mimicking other birds. Songs are generally partly or entirely learned, and different dialects often exist among neighboring populations. In most species, it is the males that sing, to attract females or to warn other males to stay away from an established territory. Studies have shown that males can distinguish the songs of their neighbors from the songs of other males. Sometimes birds sing together in duets.

***Repertoires matter*** *Most male songbirds can sing two or more different songs. Female zebra finches have been shown to consistently prefer males with more complex songs.*

***Stimulating sounds*** *Songs help coordinate the reproductive cycles of mates. They can prompt females to ovulate, build nests, and lay eggs.*

**Begging to be fed** Four hungry baby northern mockingbirds (*Mimus polyglottos*) might beg for food. Parents respond not only to gaping mouths but also to feeding calls. Calls are shorter and less complex than songs and can signal threats, hunger, sexual interest and various other elements of social behavior.



Common green magpie
*Cissa chinensis*,
family Corvidae

Red-billed blue-magpie
*Urocissa erythrorhyncha*,
family Corvidae

Eurasian nutcracker
*Nucifraga caryocatactes*,
family Corvidae

Azure-winged magpie
*Cyanopica cyanus*
family Corvidae

Characteristic long tail

Clark's nutcracker
*Nucifraga columbiana*,
family Corvidae

Red-billed chough
*Pyrrhocorax pyrrhocorax*,
family Corvidae

Alpine chough
*Pyrrhocorax graculus*,
family Corvidae

Distinctively massive bill

Rufous treepie
*Dendrocitta vagabunda*,
family Corvidae

White-necked raven
*Corvus albicollis*,
family Corvidae

## FACT FILE

**Crows** The quintessential hubbub, burnest of breast of the nuthatches most likely originated in Australia. Extensive evolution after they got to the Northern Hemisphere resulted in the many different forms of crows, rooks, choughs, nutcrackers, magpies, jays and treepies of today.

**Family Corvidae** These medium to large birds have angle-covered nostrils and fairly long legs. Colouring varies from the raven's deep black to the pollack red and green of the Asian magpies. They may eat carrion, insects or seeds or scavenge near human habitations.

***Nest robber*** The North American jay is notorious for taking the eggs or young of many songbirds.

Genera 24
Species 111

Worldwide except S. South America & polar regions

## FOOD STORAGE HABITS

Many corvids hide their surplus food in caches, to which they return long afterward. Their ability to recall the exact location of their cached nuts intrigued scientists, who believe that corvids region landmarks and possess a notably well-evolved spatial memory. Here, a Clark's nutcracker buries nuts for later in a shallow hole in the ground.

## CONSERVATION WATCH

**Dwarf jay** The dwarf jay (*Cyanolyca nanus*) is a [illegible] species, [illegible] blue bird that is endemic to a small [illegible] in southern Mexico. Although [illegible] status has been [illegible] [illegible] to more significant [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]

## FACT FILE

**Birds of paradise and bowerbirds**
These four groups of birds are found only in New Guinea, Australia, and the Moluccas. The males court females by showing elaborate powers for display on the lek (or bowerbirds) or by displaying their bizarre plumage in elaborate courting rituals (in the case of birds of paradise).

**Family Paradisaeidae** The birds of paradise are stout- or long-billed and strong-footed birds similar in crown, shape and appearance. But they are distinguished by their plumes: plumage which the males show off singly or in groups to attract females. They live in mountain forests.

Genera 16
Species 41
New Guinea & satellite islands, E. Australia, N. Moluccas

**Family Ptilonorhynchidae** Most bowerbirds live in forested areas, although others prefer the more open woodlands of the Australian bush. Most species can mimic birdcalls or other sounds, and several species are called lyrebirds because of their lyre-like tails. They eat mostly fruit and other plant matter, although their nestlings are sometimes fed insects or even other birds' nestlings.

Genera 8
Species 18
New Guinea & satellite islands, Australia

*Bower on display*

## CONSERVATION WATCH

**Blue beauty** The uniquely plumed blue bird of paradise (*Paradisaea rudolphi*), which lives in montane forests in New Guinea, is one of several vulnerable members of the Paradisaeidae family. Threats to its survival include loss of habitat and hunting for its feathers. Parts of its range are still inaccessible.

White-eyed river martin
*Pseudochelidon sirintarae*,
family Hirundinidae

White-winged swallow
*Tachycineta albiventer*
family Hirundinidae

White-banded swallow
*Amicorse fasciata*
family Hirundinidae

Black lark
*Melanocorypha yeltoniensis*
family Alaudidae

This large lark lives in the deserts of northern Africa and southwestern Asia.

Horned lark
*Eremophila alpestris*,
family Alaudidae

Greater hoopoe-lark
*Alaemon alaudipes*
family Alaudidae

Greater short-toed lark
*Calandrella brachydactyla*,
family Alaudidae

Black-crowned sparrow-lark
*Eremopterix nigriceps*
family Alaudidae

## FACT FILE

**Larks and others** This group—larks, martins, swallows, wagtails, and pipits/longclaws—was once thought to constitute related families. Molecular research has since revealed that they are quite disparate.

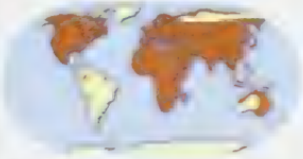
**Family Hirundinidae** Typical swallows are often recognized by their outer tail quills, which extend into long, narrow filaments. However, some species have squared tails. Many are strong migrants and are usually silent except near the nest. Like swallows, martins feed on insects taken during flight.

Genera 21
Species 84

Cosmopolitan except polar regions

**Family Alaudidae** Of the lark family, the skylark has the most impressive vocalizations, because of these it has been introduced to many parts of the world. Other larks also sing well while flying or perching. Larks have long legs and hind toes and walk rather than hop. They eat insects, other invertebrates, seeds, and grain.

Genera 19
Species 90



Cosmopolitan except C. & S. South America, E. N. Australia

***Courtship***
The courtship of the male horned lark *Eremophila alpestris* involves complicated aerobatics.

## CONSERVATION WATCH

**Under threat** The Botelian nuthatch *Tachycineta bicolor* is a vulnerable species on the Endangered Species Act of the United States. Farming, it is threatened mainly over human settlements. It is flocked to complaints using monitoring predators of the breeding season.

## FACT FILE

**Family Campephagidae** Birds in this family are known as cuckooshrikes because their bustle of feathers on the [illegible] and undulating flight feathers are reminiscent of the cuckoos. The [illegible]ration of cuckooshrikes varies markedly among the different genera. These mostly secretive birds forage for insects and fruit in trees, and build tiny, saucer nests high up in the branches.

Genera 7
Species 81

Australia & Melanesia to S. & E. Asia. [illegible]

**Family Motacillidae** These small, slender, often long-tailed birds are known as wagtails and pipits. They mostly nest on the ground and feed on insects. The typical wagtails are often found near running water, on riverbanks, and in moist grassland areas. Pipits are very widespread, and prefer open country.

Genera 5
Species 64

[illegible] North America.

*Gray wagtail*
[illegible]

## CONSERVATION WATCH

**Small range** The Sharpe's longclaw (*Macronyx sharpei*) is a sedentary, terrestrial, pipit-like member of the Motacillidae family. Endemic to Kenya, it is listed as endangered because its habitat is very small and highly fragmented. The remaining habitat is expected to decrease by [illegible] half over the next decade.

Scarlet minivet
*Pericrocotus flammeus*,
family Campephagidae

Bar-bellied cuckoo-shrike
*Coracina striata*,
family Campephagidae

Black-faced cuckoo-shrike
*Coracina novaehollandiae*,
family Campephagidae

Varied triller
*Lalage leucomela*,
family Campephagidae

Ranges nomadically through the woodlands of Australia

Ashy minivet
*Pericrocotus divaricatus*,
family Campephagidae

Wagtails are so called because of their habit of waving their tails up and down

Rosy pipit
*Anthus roseatus*,
family Motacillidae

Madagascan wagtail
*Motacilla flaviventris*,
family Motacillidae

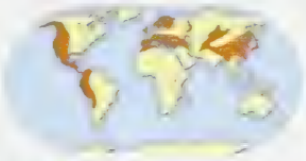
Red-throated pipit
*Anthus cervinus*,
family Motacillidae

## FACT FILE

**Bulbuls and others** These are small to medium birds of diverse families found in various parts of the world. They primarily eat insects and fruit. The gray hypocolius is one of three unique wetland birds whose habitat has been damaged by the recent wars in Iraq

**Family Cinclidae** The only truly aquatic passerines, dippers are rarely seen far from the clear, swiftly flowing streams where they feed on aquatic insect larvae and occasionally small fishes. They usually catch their prey by diving into the water and swimming or walking along the bottom. They use their wings to maneuver underwater

Genera 1
Species 5



W. North & N.W. South America, Eurasia

**Family Bombycillidae** Waxwings get their name from red, wax-like droplets that form at the tip of each secondary wing feather; these serve no known function. These very gregarious, often fawn-colored birds have sleek silhouettes and vagrant tendencies, appearing suddenly in unlikely places.

Genera 5
Species 8

North America to N.W. South America, Eurasia

**Family Troglodytidae** Wrens are a New World family, with one exception, the winter wren, which is thought to have crossed the Bering Sea to Asia and Europe. Most are not strong fliers and remain sedentary

Genera 16
Species 76

# DISPLAYS AND LEK BEHAVIOR

Because birds respond strongly to visual signs, much of their communication revolves around displays. These may serve a number of functions, including courtship, greeting, threat, submission, or distraction of predators. Courtship displays themselves vary widely, and may involve ritualized flying, constructing elaborate structures, demonstrating skills, or performing such singular actions as the male manakin's brushing of the female's throat with his tail feathers. In some cases, only the male displays, and the female is merely a spectator; in other cases, the male and female perform together. Many courtship displays involve showing off plumage, especially that found on the most visible parts of the body, such as the head, neck, breast, upper wings, or tail. In some cases, many males gather together in staging areas called leks, where they compete to attract females. Most birds are monogamous, forming pairs for one or more breeding seasons.

**Trying to impress** A male great bowerbird (*Chlamydera nuchalis*) (above) displays in front of a female who inspects his handiwork in the bower he has constructed. The species of bowerbirds in which the males are relatively drab build more elaborate bowers than those in which the males are more colorful. Bowers may take different shapes and may be decorated with various small objects. After mating, female bowerbirds go away to build separate, cup-like nests.

***All together*** *Male raggiana birds of paradise (below) perch in groups and vie with each other for the attention of females by simultaneously quivering their long, lacy, colorful flank plumes (which they spread for maximum effect) and by calling hysterically.*

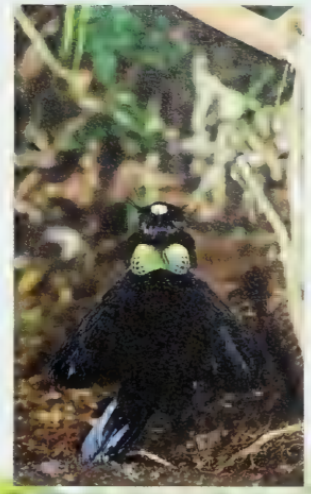
***Groupings*** *Male raggiana birds of paradise typically gather in groups of three to eight. Other species such as the greater bird of paradise (*Paradisaea apoda*) may gather in groups of as many as 20.*

***Choosing a suitor*** *Dull female raggiana birds of paradise visit the lek to observe the males' displays. Studies have shown that most females mate with the same male, presumably the one that is most dominant*

**Spectacular gatherings** Birds of paradise, which live in the forests of New Guinea, eastern Indonesia, and Australia, are justly famous for their ornate plumage and their impressive displays. Males of different species have different courtship rituals; the best known are those of the *Paradisaea* genus—such as the raggiana bird of paradise (*Paradisaea raggiana*) (above)—in which the males congregate in leks in the forest. The males use their strong feet to perch. They then spread their colorful plumes while posturing and dancing in unison. Females observe the show and choose their mate.

**Elegance in the forest** A male superb lyrebird (*Menura novaehollandiae*) (left), which lives in the forests of southeastern Australia, is reknowned for having one of the most stunning of avian displays. To attract a mate, it makes use of its unique tail, the two outer feathers of which are shaped like a Greek lyre, hence its name. The bird stands on a mound and spreads its tail into a spectacular fan. It then throws its tail forward over its head and vibrates the plumes as it dances and sings

**Going solo** The male western parotia (*Parotia sefilata*) (right) of New Guinea may perform in dispersed leks or by itself. It stands in a small, cleared performing ground in the forest and dances to attract females. Other types of passerines, such as the superb bird of paradise and the riflebirds, also perform by themselves, spreading their wings while perched.



**Saving the best display for last** When a visiting female raggiana bird of paradise (below, right) shows enough interest in a courting male to land on his perch, he begins his most impressive show. He leans forward until his body is nearly inverted, then extends his colorful wings and clasps them together, giving the female a better view of his brilliant plumage. This is a very strenuous exercise for the male. After mating, the female will fly off and the male will resume his displays in the quest for another mate. The males are not involved in the raising of offspring.

***Inspiring humans*** *The display dances of male raggiana birds of paradise have inspired the native people of eastern New Guinea to adorn themselves with the birds' plumes and perform ceremonial dances of their own. The raggiana bird of paradise is the national bird of Papua New Guinea. Trade in them is controlled, and non-nationals cannot possess a bird of paradise or its plumes.*

***Different strokes*** *Male birds of paradise have different routines, depending on their species. King birds of paradise (*Cicinnurus regius*) invert themselves even more than the raggiana, by hanging under branches.*

***Showing interest***

## FACT FILE

**Babblers, thrushes, and others** This grouping has been extensively restructured by DNA analyses. It includes some of the world's best-known birds, such as the European and American robins, the common nightingale, and the dunnock.

**Family Muscicapidae** The Old World flycatchers (such as the pied flycatcher left, with the female at the nest and the male below) are small, insect-eating birds that live in wooded areas. They often sit on low perches in dense cover, then fly off to catch insects in flight.

Genera 48
Species 275

N. Alaska, N.E. Canada, Africa, Eurasia to N. Melanesia

**Family Petroicidae** Although known as robins, these common Australasian birds are not related to European nor American robins, only resembling them in shape, size, and nature. They live in forests and woodlands.

***Red-capped robin***
*The red-capped robin*

Genera 13
Species 45

**Family Prunellidae** These birds, [illegible] as accentors, look like slender-[illegible]ed sparrows. They prefer high-[illegible]tude habitats, and forage for seeds [illegible] berries. They insulate their [illegible] level nests with feathers.

Genera [illegible]
Species 13

Arabian babbler
*Turdoides squamiceps,*
family Timaliidae

Large wren-babbler
*Napothera macrodactyla,*
family Timaliidae

Malay rail-babbler
*Eupetes macrocerus,*
family Eupetidae

Forages on the forest floor in Southeast Asia's rain forests

Eastern whipbird
*Psophodes olivaceus,*
family Eupetidae

Black-throated thrush
*Turdus atrogularis,*
family Turdidae

American robin
*Turdus migratorius,*
family Turdidae

Fluffy-backed tit-babbler
*Macronous ptilosus,*
family Timaliidae

Builds dormitory nests to sleep in

Chestnut-crowned babbler
*Pomatostomus ruficeps,*
family Pomatostomidae

## FACT FILE

**Family Turdidae** Thrushes live in most parts of the world. Familiar members of this family are the Eurasian blackbird and the American robin. They vary in color and habitat preferences. The sexes are usually alike. They eat fruits and animal prey, mostly on the ground.

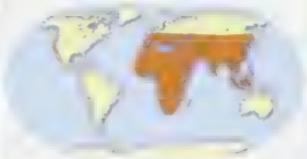
***Fine singer*** *The white-rumped shama (Copsychus malabaricus) has a fine voice that carries far and rivals that of the nightingale in its richness.*

Genera 24
Species 165

Cosmopolitan except W. & C. Australia, New Zealand

**Family Timaliidae** Babblers are mainly Old World birds that live in warm areas and eat insects. They prefer wooded habitats, where they live in undergrowth and foliage. They are small, highly social birds. Most species are a nondescript brown

Genera 50
Species 273



W. coastal USA, Africa, tropical to temperate Eurasia, E. Asian is

**Family Pomatostomidae** These birds are known as Australian babblers. Isolated in Australia and New Guinea, they have evolved convergently with the true babblers, imitating their appearance and behavior. M[illegible] are gray, white, and [illegible]

***Anyone home?***
[illegible]

## FACT FILE

**Old World warblers and others** This group of birds is characterized by the impressive singing abilities of many of its species. Warblers and their allies are for the most part insectivores, but some species also eat fruit and other items. The strange African bald crows are anomalous here, and the gnatcatchers are exclusively American.

**Family Sylviidae** Most warblers are residents of the Old World. They live in woodland, scrub, and forest. Many breed at high latitudes or high altitudes but migrate over sometimes very long distances to warmer winter climates. Their navigational abilities appear to have a strong genetic component.

Genera 48
Species 265

Africa, Eurasia to Australasia & Oceania, W. Alaska

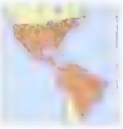
***Tiny songster***
*The golden-crowned kinglet (Regulus satrapa) inhabits coniferous forests. The tiny, plump warblers in its genus are characterized by a patch of vivid red or yellow on the crown.*

**Family Picathartidae** The bald crows, or rockfowl, are unusual birds that look like long-legged thrushes. Their bare heads are colored either orange-yellow or blue and pink. They inhabit dense forests in West Africa, where they build bowl-like mud nests. They eat insects, amphibians, and fruit.

Genera 1
Species 2

Equatorial West Africa (Guinea to Gabon)

**Family Polioptilidae** The insect-eating gnatcatchers are very small birds, even when their long tails are taken into account. Most species are found only in Central and South America. Notable is the long-billed gnatwren, whose bill [illegible] one-third of the [illegible]



Genera 3
Species 14

Temperate North America to subtropical South America

Some colonies number in the millions

Red-billed quelea
*Quelea quelea,*
family Ploceidae

Southern red bishop
*Euplectes orix,*
family Ploceidae

Long-tailed widowbird
*Euplectes progne,*
family Ploceidae

Spot-winged starling
*Saroglossa spiloptera,*
family Sturnidae

Amethyst starling
*Cinnyricinclus leucogaster,*
family Sturnidae

Metallic starling
*Aplonis metallica,*
family Sturnidae

Builds globular hanging nests in trees in large colonies

Red-billed buffalo weaver
*Bubalornis niger,*
family Ploceidae

Gray-headed social weaver
*Pseudonigrita arnaudi,*
family Passeridae

This weaver is a member of the Old World sparrow family

## FACT FILE

**Starlings and weavers** Starlings are found throughout the Old World. They have also been deliberately introduced to and prospered in North America and in countries outside their endemic ranges. Weavers are finch-like birds restricted mostly to Africa.

**Family Sturnidae** The starling family includes the common starling, one of the most familiar of garden birds. This stumpy, relatively short-tailed bird has a confident strut and a pugnacious air. Although some starlings forage on open country and eat insects, most species live in rain forests and eat fruit.

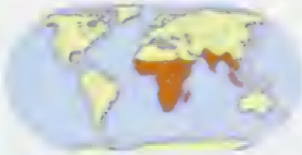
***Safari bird*** The superb starling (*Lamprotornis superbus*), number one on safari in East Africa, is commonly seen sunning its plumage, marked in one of the more beautiful of the starlings.

Genera 25
Species 110

Africa, temperate & tropical Eurasia to N.E. Australia & Oceania

**Family Ploceidae** The weaver birds are notable for their nests. The males of some species build their own nests by looping and knotting blades of grass in a process akin to basket-weaving. Other species build large communal nests of thorns or sticks. Red-billed queleas live in huge flocks and feed on grain.

Genera 11
Species 108



Sub-Saharan Africa, S. & S.E. Asia, Sri Lanka, parts of Europe

## CONSERVATION WATCH

**Weaver weaver** This critically endangered Mauritian species, formerly robust, is a small, unobtrusive bird, whose [illegible] habitat, [illegible] and the introduction of predators such as rats have led to a precipitous decline in its numbers.

## FACT FILE

### Waxbills, whydahs, and finches

[illegible]

**Family Fringillidae** Almost all finches within this family have red or yellow in their plumage. They are migratory birds that inhabit temperate climates. They have only one large conical feathered on each side. The form is varied. They [illegible] insects, even during nesting.

*Specialized bill*

[illegible]

Genera [illegible]
Species [illegible]

[illegible]

**Family Viduidae** Whydahs get their name from the Portuguese word for a widow's veil, thanks to the males' very long tail. Each species of whydah is a brood parasite of a particular waxbill species, and their juveniles even have the same [illegible] and swagging [illegible] as the host species' young.

Genera [illegible]
Species [illegible]

[illegible]

## VIREO NEST

[illegible]

## FACT FILE

**Tanagers and bananaquits** These small to medium-sized, [illegible] birds in the New World, mainly in tropical and mountainous regions of South America. Most are multicolored, though some species are in varying shades or drawing neither from flowers. Most of them prefer either flowering or fruit-laden areas, but some species have no distinct habitat preference.

**Family Thraupidae** The Andes are the center of radiation for the tanagers. A few species of tanager are drab and secretive, but the family also includes some of the most colorful birds. The honeycreepers have long, thin, delicate bills for extracting nectar. The insect specialists have heavy, notched bill. Most tanagers build cup-shaped nests among moss or dead leaves. Females carry out most of the nesting tasks.



Genera [illegible]
Species [illegible]
[illegible]
North, Central and South America

***Superb plumage***
The [illegible] tanager (Tangara fastuosa) lives in a small territory. Their numbers have declined greatly due to trapping for the pet trade and habitat loss.



**Family Coerebidae**
The bananaquit is the only member of this family. It lives in the tropics of South America, north to Mexico and the Caribbean, and it sometimes ventures to the southern tip of the United States. This very small bird has a slender, curved bill adapted for taking nectar, which it sometimes extracts by piercing the flower from the side, without pollinating it. It is often seen in gardens.



Genera [illegible]
Species [illegible]
[illegible]
[illegible]

## CONSERVATION WATCH

**Azure-rumped tanager** (Tangara cabanisi) is one [illegible] species that is given [illegible] status of the Threatened Species [illegible] It is a [illegible] species that lives in Southwest Africa and [illegible] where the conversion of its forest habitat [illegible] plantations is causing a decline in its numbers.

## FACT FILE

**New World warblers** Also known as [illegible] this family are the [illegible] equivalents of the Old World flycatchers. Despite their name, they are not renowned for their [illegible] They occupy nearly every habitat south of the tundra.

**Family Parulidae** These warblers are active foliage gleaners. They sometimes form mixed-species "guilds" comprising species that each forage in a different way. Most build nests on trees, shrubs or [illegible]. Unlike their Old World counterparts, they only have one large [illegible] in the wild.

Genera 24
Species 112

[illegible] South America, West Indies

## SEXUAL PLUMAGE

Most New World warblers are brightly colored and patterned. Among the North American species, the breeding males are often more brightly colored than females, but both sexes usually molt into more drab plumage before their autumn migrations.

***Variety*** [illegible]

## CONSERVATION WATCH

**Mexican marsh-dweller** The Altamira yellowthroat (*Geothlypis [illegible]elata*), endemic to northeast Mexico, is listed as vulnerable. This [illegible] occupies a few small [illegible] of freshwater marsh within its [illegible] range. Its habitat has been [illegible] due to cattle ranching.

## FACT FILE

**Buntings, cardinals, and troupials** These birds are either confined to the New World or else originated in the Americas and spread to the Old World in successive waves of colonization. They are quite diverse, but most eat seeds and use plant matter to build cup-shaped nests.

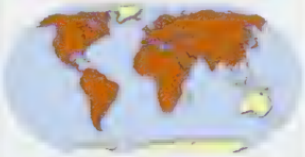
**Family Icteridae** This family, often misleadingly referred to as "American blackbirds," is the most ecologically and morphologically diverse group of New World songbirds. The family is predominantly tropical. Very few of its species are true forest birds, preferring swamps, marshes, savannas, arid scrub, or open woodlands. Males in this family are much larger than females.

**Genera** 26
**Species** 98

North America to South America, West Indies

**Family Emberizidae** Included in this family are New World sparrows and finches and Old World buntings. These small birds all have short, conical bills adapted to eating seeds, but they tend to feed their young with insects. They are primarily terrestrial and most have brown-streaked plumage. The snow bunting has the distinction of breeding further north (in northern Greenland) than any other land bird. These birds tend to have small song repertoires.

**Genera** 73
**Species** 308



Cosmopolitan except Madagascar, Indonesia & Australasia

***A standout***
*Cardinals, such as the painted bunting (Passerina ciris), tend to be much more brightly colored than other buntings. The male in particular has notably multi-hued plumage.*

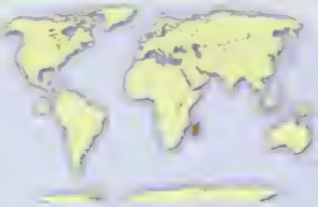
## CONSERVATION WATCH

**Black news** The saffron-headed blackbird (*Xanthocephalus xanthocephalus*) is one of several vulnerable members of the Icteridae family. It is trapped for the pet trade, due to its striking looks. Also, pesticide use and other factors are threatening its grassland habitat.

# Evolution of bills

The size and shape of birds' bills vary, adapted to their diets and food-gathering methods. It was Charles Darwin who first offered convincing proof that such physical features are not immutable, and that species change over time in response to their environments. He theorized that Galápagos Islands finches, which differed most noticeably in terms of bill size and shape, were all descended from a common ancestor and had evolved to exploit different ecological niches that were not being filled by other animals. Genetic mutations that helped certain birds thrive were likely to be passed on to successive generations. This adaptive radiation is most noticeable on remote islands, where outside influences and competitor species are almost absent.

**A productive relationship** The brilliantly colored iiwi (above), one of the Hawaiian honeycreepers, has a bill that allows it to easily reach nectar-bearing flowers. Conversely, which it feeds in turn, may be seen hanging upside down while feeding.



**Isolated habitats** Left to right: Hawaii; Galápagos Islands; Madagascar.

***Rapid spread*** *Specialized species that also eat insects (H1 and H3) or seeds (H2) specialized rapidly—within a few hundred thousand years—to fill Hawaii's unoccupied ecological niches.*

***Different appetites*** *[illegible]*

***Limitations*** *[illegible]*

***Special skills*** *One Darwin finch species (G1) has learned to extract insects from under bark or crevices in which using a cactus spine or twig. The largest of the ground finches (G2) uses its thick bill to eat large seeds.*

**A rainbow of differences** *[illegible]*

**Diversity on a large island** The vangas are a diverse family (called Vangidae) of passerines found only on the island of Madagascar. The 22 species all prey on invertebrates or small reptiles, but they have evolved to fill many different niches on a long-isolated island whose very different habitats span a latitudinal range equal to that of California. The vangas pictured are: M1: Sickle-billed vanga (*Falculea palliata*); M2: Pollen's vanga (*Xenopirostris polleni*); M3: Helmet vanga (*Euryceros prevostii*); M4: Red-shouldered vanga (*Calicalicus rufocarpalis*); M5: Blue vanga (*Cyanolanius madagascarinus*).

***A variety of roles*** *The vangas have specialized so much that there are almost as many genera as species in this group. The long bill of M1 is ideal for feeding in spiny forests. M2 probes in dead wood; M4 gleans insects from bushes and in flight.*

***Similarities to other birds*** *Individual vanga species have filled niches similar to those of birds elsewhere and have thus grown to resemble them. The M3, for example, recalls a small hornbill.*

**Niche filler** A Chabert's vanga (*Leptopterus chabert*) (left) perches on a branch in Madagascar. This bird is an insectivore that catches its prey by flying forth from a perch, or else by behaving like a woodswallow.

***Blood-sucker*** *One finch (G5) is also known as the "vampire finch" due to its habit of pecking seabirds in order to drink their blood.*

***Versatile bird*** *One of the ground finches (G6) evolved a longer bill, which allows it to feed on cactus flowers and fruits as well as seeds. Diet specialization is especially important in lean times*

**Spawning a scientific revolution** Modern genetic analyses have proven Darwin right, showing that the 14 species of Galápagos-based birds now known as Darwin's finches are indeed descended from one species, a seed-eating finch that arrived there from the South American mainland. The Galápagos birds pictured are: G1: woodpecker finch (*Camarhynchus pallidus*); G2: large ground finch (*Geospiza magnirostris*); G3: warbler finch (*Certhidea olivacea*); G4: masked booby (*Sula dactylatra*); G5: sharp-beaked ground finch (*Geospiza difficilis*); G6: common cactus-finch (*Geospiza scandens*).

**Few predators** A Galápagos hawk (*Buteo galápagoensis*) (right) soars above Fernandina Island. It is one of the few land birds, apart from the finches, that has managed to colonize these remote islands. It is one of three raptor species found there.

# REPTILES

# REPTILES

PHYLUM Chordata
CLASS Reptilia
ORDERS 4
FAMILIES 50
GENERA 1,212
SPECIES 8,163

Reptiles are often thought of as relics of an age gone by, leftovers from the age of the dinosaurs. But in fact reptiles are continuously evolving. Modern species are the product of over 300 million years of evolution since the basal amniotes split into two lineages: one leading to mammals (Synapsida) and the other to birds and reptiles (Diapsida). The diapsid reptiles diverged into two main groups, the Lepidosauria (scaly reptiles—lizards, snakes, amphisbaenas, and tuataras) and the Archosauria (ruling reptiles—crocodiles, pterosaurs, dinosaurs, and ancestral birds) in the Triassic. Turtles appeared in the fossil record about 210 million years ago. Even though current skeletal shapes look similar to species living 200 million years ago, today's reptiles are highly specialized.

**Parental care** Some species of crocodiles guard their nests and carry their young to the water after they hatch. Some may wait, then pick up their young a year later.

## THE CLEIDOIC EGG

The closed system of the egg—where water, nutrients, and waste are stored until hatching—allowed reptiles to be independent of water and invade land. All eggs need to respire; they have tiny pores that allow oxygen to enter. Some eggs are very permeable, and if they are not buried in a moist place will dehydrate. Other species have developed very thick-shelled eggs to avoid dehydration. Eggs are sometimes retained in many snakes and lizards, and development progresses in the female. Variations on this theme led to viviparity evolving in lizards and snakes, whereby large, soft-shell, shell-less eggs were maintained in the oviduct until hatching. Where there was nutrient exchange between the female and her embryos this evolved into the formation of a placenta.

Internal fertilization was another mechanism that freed reptiles from an aquatic life. Lizards and snakes have two functional hemipenes. Tuataras abut their cloacas, and turtles and crocodilians have a penis for internal sperm transmission.

Development of impermeable skin allowed reptiles the chance to live permanently out of water without dehydrating. The epidermis radiated in diverse directions—the skin beads on gila monsters, the crests on iguanas, the keeled scales in snakes, the rattle on rattlesnakes, the scutes on turtle shells, and the armored plates on crocodiles. Reptile skin varies in its permeability to water and gas exchange.

On land, temperatures fluctuate more rapidly than in the water, so reptiles had to develop behavioral mechanisms to control their core body temperatures so that enzyme processes would function. Since, unlike mammals, most reptiles do not burn calories to maintain body temperatures, they use behavioral means, sunning themselves in the early morning hours, remaining in the shade or underground in the heat of the day, or becoming nocturnal in hot environments. Many behavioral, structural, and physiological mechanisms evolved to allow reptiles to be more efficient in using energy than mammals.

**Basking turtles** Butterflies are attracted to the yellow-spotted Nile, the eyes of yellow-spotted Amazon River turtle, Podocnemis unifilis. The turtles back to view their body temperature and to absorb ultraviolet radiation to help in the synthesis of vitamin D. The yellow dots mark the mark up and front edge (above).

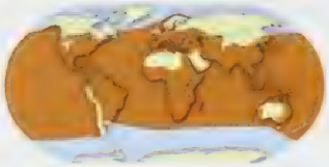
**Reptile egg** This analysis shows caught through the shell (above) and in the egg. Some gases are able to pass through the shell, and the embryo respires from the moment it is laid. The embryo develops in the egg, and the yolk feeds it. The mature hatchling (above) has a large yolk, and the yolk sac is taken through the navel, and the yolk sac is taken through the navel.

**Thorny or spiny?** The thorny devil is the particular of the Australian world. Because every part of its body is covered in spines, it is safe from many predators, including snakes and most birds. Though some monitor lizards (family Varanidae) have evolved to overcome them and live

# TORTOISES AND TURTLES

CLASS Reptilia
ORDER Testudines
FAMILIES 14
GENERA 99
SPECIES 293

Turtles and tortoises are the only vertebrates that house the pelvic and pectoral girdles within a shell made of ribs fused with bone. The first fossils to show this trait appeared 220 million years ago in the Triassic period, when dinosaurs roamed the earth. The shell design has since undergone various modifications. The African pancake tortoise has a flexible flat shell allowing it to wedge into crevices; it then inflates, after which it is impossible to pull out. Softshell turtles lack a hard shell; instead, the bones are covered with a smooth leathery shell, giving them more speed. There is still controversy as to whether turtles are derived from a different lineage to other reptiles.



**Distribution** Turtles are found on all continents except Antarctica, and in all oceans: 241 species of turtles have adapted to freshwater rivers, lakes, and ponds; 45 tortoises are terrestrial; only seven species live in the oceans

**Saddleback giant** The Galápagos tortoise [illegible] a saddleback carapace. This [illegible] more [illegible] in adult male tortoises, due to enhanced mating success, [illegible] on the drier and more barren islands of the Galápagos.

**Baby leatherback** Leatherback turtles lay up to six nests of up to 200 eggs a year for decades. This hatchling has passed the first hurdle: 2 months incubating in the sand with predators digging around it. It now has to face the many threats in the sea

**Turtle skeleton** A turtle's shell has an outer layer of epidermal scutes (usually 38 on the carapace and 16 on the plastron) Under these, a shell of fused ribs (the plastron) supports the body. The vertebrae are joined to the inside of the carapace

**Swimming sea turtle** The forelimbs of sea turtles have been modified into flipper-shaped paddles that move synchronously resembling aquatic flying rather than swimming. Sea turtles are so adept in the water that they rarely leave it except to nest. Freshwater turtles swim using all four limbs in turn.

## EVOLUTION SHELLED OUT

In addition to the shell, turtles and tortoises have evolved many unique features. Turtle muscles are able to withstand high levels of lactic acid, so they do not tire after swimming rapidly. They also fill their large urinary bladders with water for ballast to maintain buoyancy.

Turtles and tortoises occupy niches as predators, grazers, croppers, and scavengers. Some have gut flora to digest plant cells; others are seed dispersers. Wood turtles stomp on the ground with their front feet, then eat the earthworms that come out of the ground.

Some sea turtles and freshwater turtles nest within a few days in tremendous numbers on the same nesting beach. These mass nestings, known as arribadas, evolved to swamp local predators—it would be impossible for them to eat all of the eggs or kill all of the females. The success of these adaptations has helped turtles to survive over millions of years; now, as a result of human intervention, two-thirds of all turtle species are being carefully monitored by the IUCN.

Matamata characterized by its long snorkel nose, which allows it to lie in shallow water and reach the surface to respire without frightening its prey

Matamata
*Chelus fimbriatus*

Twist-necked turtle
*Platemys platycephala*

Twist-necked turtle is the only species of turtle known to have triploid chromosomes in some populations

Common snake-necked turtle
*Chelodina longiovis*

Helmeted turtle
*Pelomedusa subrufa*

Giant Amazon river turtle
*Podocnemis expansa*

Chelidae Fitzroy turtle
*Rheodytes leukops*

Serrated turtle
*Pelusios sinuatus*

Hilaire's toadhead turtle
*Phrynops hilari*

Victoria short-necked turtle
*Emydura victoriae*

## FACT FILE

**Matamata** The matamata, relying on its camouflage, lies waiting for small fishes to pass. With lightning speed, it opens its mouth and thrusts out its neck simultaneously, creating a sucking force that pulls fishes into its mouth.

Up to 18 in (46 cm)
Aquatic
♀♂ Dimorphism
10–28
Climmer

Amazonia (N. South America)

**Giant Amazon river turtle** Selection for fast incubation was influenced by the unpredictability of rising river levels. The eggs hatch in 45 days, and nest temperatures often reach 104°F (40°C), the highest known for any turtle.

Up to 42 in (107 cm)
Aquatic
♀♂ TSD
60–150
Climmers dependent

Amazon & Orinoco basins (N. South America)

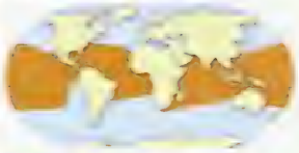
## BEGINNING OF LIFE

Sea turtles lay their eggs on the same beaches that their ancestors have used for millennia. Once the nest has been covered with sand, the eggs are left to chance to go undetected by predators. Hatchlings must race to the sea, running the risk of predation by hungry mammals and birds, to the dubious safety of waters filled with even more predators. Survival rates for some species may be as low as 1 in 50,000.

*Hatchling flatback turtles*

## FACT FILE

**Green turtle**



**Olive Ridley turtle**

## SHELL SHAPES

Loggerhead
Caretta caretta

Green turtle
Chelonia mydas

Olive Ridley turtle
Lepidochelys olivacea

Kemp's Ridley turtle
Lepidochelys kempii

Leatherback turtle
Dermochelys coriacea

Hawksbill turtle
Eretmochelys imbricata

Flatback turtle

Ganges softshell turtle
*Aspideretes gangenticus*

Indian flap-shelled turtle
*Lissemys punctata*

Australian pig-nosed turtle
*Carettochelys insculpta*

Spiny softshell turtle
*Apalone spinifera*

Nile softshell turtle
*Trionyx triunguis*

Nile softshell absorbs much of the oxygen it needs by pharyngeal respiration and by filtration through the skin

Smooth softshell turtle
*Apalone mutica*

## FACT FILE

**Ganges softshell turtle** [illegible] strongest. This [illegible] [illegible] in the Ganges River [illegible] [illegible] that are [illegible] [illegible] of traditional funeral [illegible]

[illegible] India, [illegible] Pakistan, Bangladesh, Burma

## HEAT AND SEX

[illegible] some species of turtles, as in most lizards, [illegible] genetic, referred to as GSD, or genetic sex determination. In most turtles studied, some species, all monogamous, and the fertile sex is controlled by the incubation temperature, referred to as TSD, or temperature sex determination. The temperature during the middle third of the incubation period determines what the sex of the hatching turtle will be. Females are produced at extreme low and high temperatures and males at intermediate temperatures. Thus a female can control the sex of her offspring by where she lays her eggs: nests out in the full sunlight produce females, while nests in the shade produce males; the first nests in summer produce females, while the last nests in the fall produce males.

**Wood turtle hatching**
[illegible]

## CONSERVATION WATCH

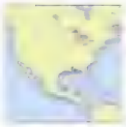
The 198 species of [illegible] on the IUCN Red List are [illegible] as follows:

7 [illegible]
1 [illegible]
29 [illegible]
46 [illegible]
57 [illegible]
1 [illegible]
[illegible]
[illegible]
[illegible]
1 [illegible]

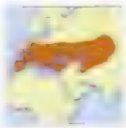
## FACT FILE

**Diamondback terrapin** [illegible]

**Ringed sawback** [illegible]



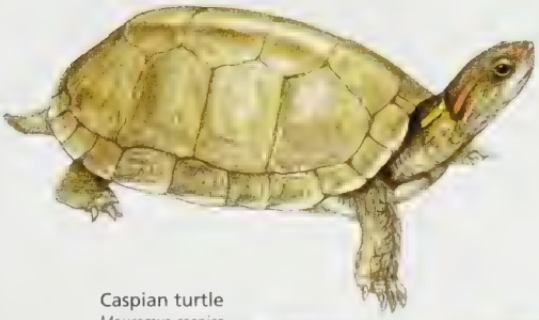
**European pond turtle** [illegible]



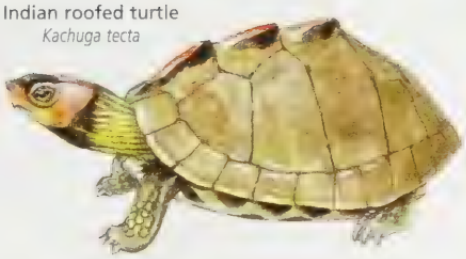
**Painted turtle** [illegible]

**River cooter** [illegible]

**Furrowed wood turtle**
*Rhinoclemmys areolata*



**Indian roofed turtle**
*Kachuga tecta*



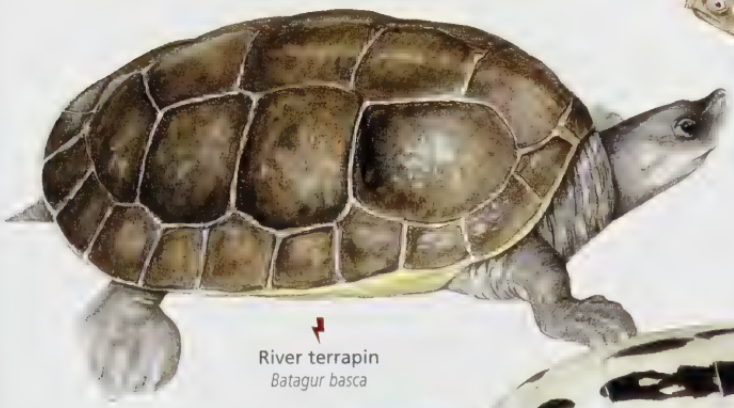
**Caspian turtle**
*Mauremys caspica*

**Malayan box turtle**
*Cuora amboinensis*

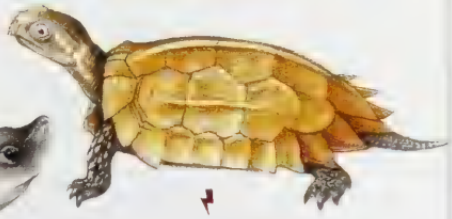
**Malayan snail-eating turtle**
*Malayemys subtrijuga*

One of the few freshwater turtles to nest on ocean beaches. The hatchlings can live for at least 2 weeks in sea water

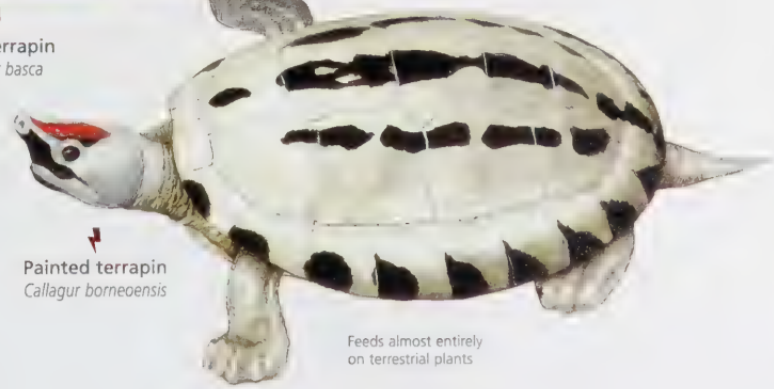
**Spotted pond turtle**
*Geoclemys hamiltoni*



**River terrapin**
*Batagur basca*



**Black-breasted leaf turtle**
*Geoemyda spengleri*

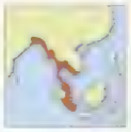


**Painted terrapin**
*Callagur borneoensis*

Feeds almost entirely on terrestrial plants

## FACT FILE

**River terrapin** During the breeding season, from September to November, the males head coloration changes. The nostrils become blue, the lip white, the head deep blank, and the neck and front limbs deep red and black. Sand mining is destroying the preferred nesting beaches of this species.



E. India & Bangladesh to Burma, Thailand, Cambodia & Indonesia

**Painted terrapin** Painted terrapins are exploited for their eggs, which fetch five times the price of chicken eggs. Habitat destruction is also exacerbating the decline of the species. Only one or two rivers harbor more than a hundred nesting females.

S. Thailand, Malaysia, Sumatra & Borneo

## LEG ADAPTATIONS

From the shape of the leg, foot, and claws, it is possible to deduce what habitat the turtle was adapted for, but not necessarily where it is living today.

***Sea turtle*** *The forelimbs of sea turtles are aerodynamically designed to fly through water. They are tapered from tip to base like the wings of an albatross. There is no webbing, as the bones are fused together within the flippers.*

***Land tortoise*** *This animal is perfectly [illegible] walking with a [illegible] gait. [illegible] The leg from [illegible] flatter, the [illegible] and the [illegible] leg [illegible] to support [illegible] weight [illegible]*

***Pond turtle*** *[illegible]*

## FACT FILE

**Leopard tortoise** During courtship the male mounts the female, butting her into submission. After mounting, he extends his neck and releases a grunt-like bellow. Females lay 5–7 clutches of 5–30 eggs from May to October

Up to 27 in (68 cm)
Terrestrial
♀♂ Longevity
5–30
Common
Ethiopia to Natal & South Africa

**African tent tortoise** Nesting takes place from September to December, when up to three ellipsoidal eggs are laid in a single yearly clutch. The eggs hatch between April and May. The hatchlings are 1 inch (2.5 cm) long

Up to 5 in (16 cm)
Terrestrial
♀♂ Unknown
1–3
Common
Africa to Cape, South Africa

**Texas tortoise** This species feeds on the pads, flowers, and fruit of cactus in the Chihuahuan Desert. They are active early in the morning, and rest in the shade or in burrows during the heat of the day

Up to 8 in (22 cm)
Terrestrial
♀♂ TSD
1–4
Vulnerable
Texas, Mexico

## COURTSHIP

Courtship occurs in turtles that have sexual dimorphism to ensure intra-specific mating. Males come face to face with the female and present head butts or bite at her, with the forelegs on the face of the female. The number of mating vocalizations and the length of the courtship are species-specific.

Mating a female

Razorback musk turtle
*Kinosternon carinatus*

Mexican giant musk turtle
*Staurotypus triporcatus*

Big-headed turtle
*Platysternon megacephalum*

Chopontil
*Claudius angustatus*

Loggerhead musk turtle
*Kinosternon minor*

Common snapping turtle
*Chelydra serpentina*

Common mud turtle
*Kinosternon subrubrum*

Alligator snapping turtle
*Macrochelys temmincki*

Central American river turtle
*Dermatemys mawii*

## FACT FILE

**Common snapping turtle** This species is known for its ability to [illegible] forward rapidly with snapping [illegible] an adaptation for crayfish predation and for protection. These turtles are omnivores, feeding on cr[illegible] carrion, duckweed, and aquatic plants.

Up to [illegible] in ([illegible] cm)
Aquatic
♀♂ TSD
[illegible]–[illegible]
[illegible]

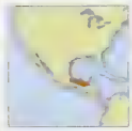
S. Canada, E. N.A., USA

**Alligator snapping turtle** The largest species of turtle in North America was being driven to extinction by the soup industry. Until recently, this rare beast could be found on American grocery store shelves in red-and-white cans.

Up to [illegible] in ([illegible] cm)
Aquatic
♀♂ TSD
8–[illegible]
Vulnerable

S.E. USA

**Central American river turtle** This highly aquatic turtle seldom leaves the water even to nest. They often nest by digging into the river bank under the water level. The eggs do not begin to develop until the river is lower.



Up to 26 in (66 cm)
Aquatic
♀♂ TSD
8–26
Endangered

S. Mexico, Guatemala, Belize

## CAMOUFLAGE

The alligator snapping turtle is a master of disguise. With flaps of loose skin hanging on its neck and filamentous algae growing on its shell, it blends in well with the logs and plants among which it sits waiting for unwary prey. Only its pink lure contrasts with its [illegible]

[illegible]

# DEATH ROW

During the last 5 years, the decimation of turtle populations has accelerated rapidly. The Turtle Survival Alliance (TSA) has been formed to monitor and attempt to reverse this trend. TSA shortlisted 25 of the most critically endangered species to raise awareness of the problem. Most of these species occur in hotspots for high biodiversity—areas that are important for the critical habitat of a number of other taxa as well. The turtles are in trouble because of overexploitation for food or traditional remedies, the pet trade, restricted range, and habitat degradation. Only five of these are suffering due to habitat degradation—15 of the 25 are on the brink of extinction because of uncontrolled exploitation by humans.

**Bogged down** The endangered [illegible] turtle (*Clemmys muhlenbergii*) is endemic to uplanded meadows and sphagnum bogs of the Piedmont and Appalachian mountains. Combined habitat degradation and fragmentation and the pet trade have led many this species. Clearing wetlands may also [illegible] extinction rate.

**Lonely giants** [illegible]

**Reaping death** There are now fewer than 400 ploughshare tortoises (below) in the wild; they are now restricted to the bamboo scrub near Baly Bay in northeastern Madagascar. Loss of consumption, the pet trade, and habitat degradation have led to their downfall. The uniquely hard shell comes from the long dome shape that extends under its head and is used in combat by the males.

**Rapid decline** The Malayan river turtle [illegible] extinct over much of its range due to harvesting of eggs and adults. Annual population has been projected at [illegible] since 2001 and 30 nests were recorded in 2000. However, the Mary River turtle (*Elusor macrurus*) of Australia [illegible] as the highest extinction risk despite [illegible] conservation efforts.

## THE WORLD'S MOST ENDANGERED TURTLES

**1. MESOAMERICA HOTSPOT**
Central American river turtle
*Dermatemys mawii*

**2. CHOCÓ-DARIÉN–WESTERN ECUADOR HOTSPOT**
Dahl's toad-headed tortoise
*Batrachemys dahli*

**3. MEDITERRANEAN BASIN HOTSPOT**
Egyptian tortoise
*Testudo kleinmanni*

**4. MADAGASCAR AND INDIAN OCEAN ISLANDS HOTSPOT**
Madagascar big-headed turtle
*Erymnochelys madagascariensis*

Ploughshare tortoise
*Geochelone yniphora*

Flat-tailed tortoise
*Pyxis planicauda*

**5. SUCCULENT KAROO HOTSPOT**
Southern speckled padloper tortoise
*Homopus signatus cafer*

**6. CAPE FLORISTIC REGION HOTSPOT**
Geometric tortoise
*Psammobates geometricus*

**7. INDO-BURMA HOTSPOT**
Striped narrow-headed softshell turtle
*Chitra chitra*

Chinese three-striped box turtle
*Cuora trifasciata*

Arakan forest turtle
*Heosemys depressa*

Burmese star tortoise
*Geochelone platynota*

Burmese roofed turtle
*Kachuga trivittata*

Leaf turtle
*Mauremys annamensis*

Yangtze giant softshell turtle
*Pelochelys swinhoei*

**8. SUNDALAND HOTSPOT**
River terrapin
*Batagur baska*

Painted terrapin
*Callagur borneoensis*

**9. PHILIPPINES HOTSPOT**
Philippine forest turtle
*Heosemys leytensis*

**10. WALLACEA HOTSPOT**
Rote snake-necked turtle
*Chelodina mccordi*

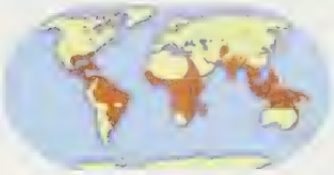
Sulawesi forest turtle
*Leucocephalon yuwonoi*

**11. SOUTHWESTERN AUSTRALIA HOTSPOT**
Western swamp turtle
*Pseudemydura umbrina*

# CROCODILIANS

**CLASS** Reptilia
**ORDER** Crocodilia
**FAMILIES** 3
**GENERA** 8
**SPECIES** 23

Alligators, caimans, crocodiles, and gharials are all crocodilians, belonging to the lineage of archosaurs, which includes the dinosaurs and birds. Crocodilians are much more closely related to birds than they are to other reptiles, and have existed for 220 million years, since the Triassic period. Part of their success is a result of being the top aquatic predator in their domain. As the body form of crocodilians has stayed the same, they are often called living fossils, but these beasts have been evolving for millions of years and are very different from their ancestors in the age of the dinosaurs. Unlike most reptiles, crocodilians are very vocal, especially during courtship.



**Distribution** Crocodilians are found in tropical, subtropical, and temperate zones worldwide: Gavialidae in South Asia, and Alligatoridae in eastern North America, Central and South America, and eastern China. Crocodylidae inhabit estuaries and freshwater streams of Africa, India, Indonesia, Australia, northern South America, Central America, and the West Indies

**Nile crocodile baby** When about to hatch, the young call from the egg. Their mother responds by scraping away the material covering the eggs. When they hatch, she gently gulps them into a pouch that has developed in the floor of her mouth, then transports them to their wetland nursery.

**Nile crocodile** Despite their ferocious look, these animals feed primarily on fishes. Those over 3 feet (1 m) mainly eat fishes that are predatory on human food fishes. Maintaining populations of this species in the wild may help the local fishing industry

### CONSERVATION WATCH

The 14 species of crocodilians on the IUCN Red List are categorized as follows:

- 4 Critically endangered
- 3 Endangered
- 3 Vulnerable
- 2 Conservation dependent
- 1 Data deficient
- 1 Least concern

## CANNIBALISM AND CARE

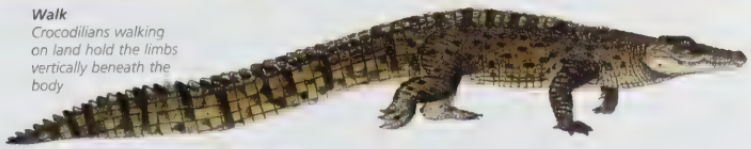
Crocodilians have an elongated, cylindrical body with short, muscular limbs and a laterally compressed tail. The massive skull is set on a short neck and features strongly toothed jaws. Crocodilians are aquatic, yet bask and nest on shorelines.

Crocodilians are oviparous, with internal fertilization. Clutches usually contain 12–48 eggs; all species studied have temperature-controlled sex determination, in which females are produced at high and low incubation temperatures and males only at a narrow range of intermediate temperatures.

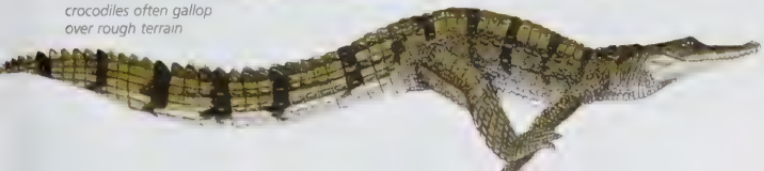
The eggs are laid in nests made of mounds of vegetation or in nests dug in the sand. Nest site selection can control the sex of the young. Both males and females of some species guard the nest. Females of some species are known to respond to the grunts of the nearly hatched embryos by opening the nests for them. The female will also carry the hatchlings in her mouth to the water, where she has bulldozed a nursery pond for them.

Females will protect their young for the first 2 months. However, males are also known to protect and maintain their territories and food supplies by killing and eating any young male crocodilians within their territory, so the female is often protecting her young from their own father. Female American alligators often stay with their young near the nesting [illegible]

***Crawl***
*Crocodiles crawl low to the ground when they are trying to conceal themselves from potential prey or predators*



***Walk***
*Crocodilians walking on land hold the limbs vertically beneath the body*

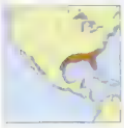


***Gallop***
*Australian freshwater crocodiles often gallop over rough terrain*

**Crocodile gaits** Although crocodiles are primarily aquatic, they use their legs for walking on land and the tail for swimming. On land, the use of ball-and-socket vertebrae allows crocodilians to have varied gaits

## FACT FILE

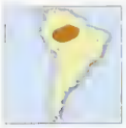
**American alligator** Populations of this species were low in the 1950s and protected as endangered in 1967. Populations rebounded in 20 years to over 800,000 animals. Hunting of some populations is now allowed, in order to control their numbers.



- Up to 19 ft (5.8 m)
- Aquatic
- Oviparous
- 10–40
- Common

S.E. USA

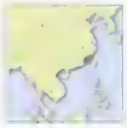
**Black caiman** This species has recently been reclassified from endangered in Brazil. Conservation efforts over more than 10 years were highly successful, with populations recuperating rapidly. A program to sustainably harvest this species is being enacted.



- Up to 20 ft (6 m)
- Aquatic
- Oviparous
- 35–50
- Conserv. dependent

Amazon Basin (N. South America)

**Chinese alligator** This species spends the majority of its life in a complex of underground burrows. The alligators build these systems with pools of water above and below ground as well as air holes for breathing.

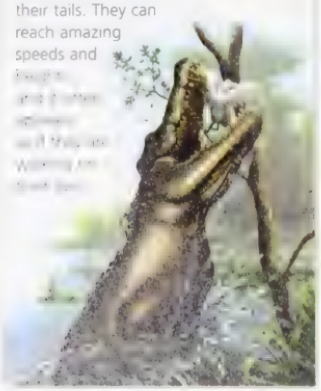


- Up to 6½ ft (2 m)
- Aquatic
- Oviparous
- 10–40
- Critically endangered

Yangtze Valley (China)

## ALLIGATOR ACTIVITY

Alligators frequently forage for fishes beneath waterbird rookeries. On occasion, for a change in diet, they will launch themselves at birds as well, using just the propulsion of their tails. They can reach amazing speeds and [illegible]



American alligator
*Alligator mississippiensis*

Black caiman
*Melanosuchus niger*

Cuvier's dwarf caiman
*Paleosuchus palpebrosus*

African dwarf crocodile
*Osteolaemus tetraspis*

Chinese alligator
*Alligator sinensis*

False gharial
*Tomistoma schlegelii*

Mugger
*Crocodylus palustris*

Saltwater crocodile
*Crocodylus porosus*

Orinoco crocodile
*Crocodylus intermedius*

Spectacled caiman
*Caiman crocodilus*

Black tail bands are characteristic of the caiman

Siamese crocodile
*Crocodylus siamensis*

Five clawed digits are present on the forelimb

American crocodile
*Crocodylus acutus*

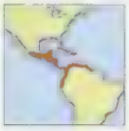
Gharial
*Gavialis gangeticus*

Only the male has a distinct boss on the tip of the snout

Nile crocodile
*Crocodylus niloticus*

## FACT FILE

**American crocodile** This species was once abundant and widespread but was extirpated in many regions due to the skin trade and habitat destruction. Populations have not recuperated in many areas because of habitat loss and continued hunting.



Up to 23 ft (7 m)
Aquatic
Oviparous
30–40
Vulnerable

S. Florida (USA), Mexico to Colombia, Ecuador

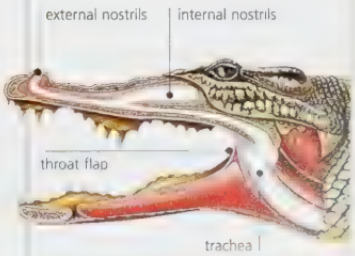
**Nile crocodile** Maturity is reached in 12–15 years at 6–9 feet (1.8–2.8 m). The female guards the nest, opens it at hatching, and carries the hatchlings to the water. Both parents guard the young for up to 2 months.

Up to 19 ft (6 m)
Aquatic
Oviparous
16–80
Common

Sub-Saharan Africa

## ANATOMY

Crocodilians have various adaptations to an aquatic life. The position of the eyes, ear openings, and nostrils at the highest part of the body allows them to lie concealed just below the surface of the water when stalking prey. A secondary palate lets them breathe with the mouth closed. A flap of skin in the throat prevents water from entering the throat when the jaws are being opened to capture prey.



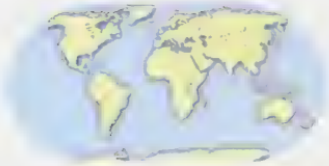

## CONSERVATION WATCH

**Fashion victims** Skins from 15 species of crocodilians have been sold as luxury leather products. This has had a negative effect on wild populations of crocodilians. Crocodile farms, meanwhile, are vanishing due to high costs, lower demand, and lower prices. Sustainable use of wild populations seems to be more feasible in the long term.

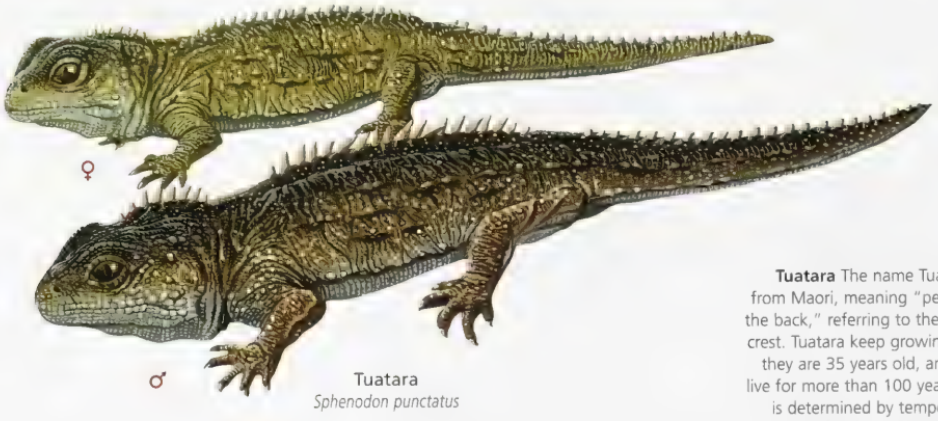
# TUATARA

CLASS Reptilia
ORDER Rhynchocephalia
FAMILY Sphenodontidae
GENUS Sphenodon
SPECIES 2

The tuatara is often called a "living fossil" and is now only to be found on the islands of New Zealand. It is the only survivor of a large group of reptiles that roamed with the dinosaurs over 225 million years ago, the rest of which became extinct 60 million years ago. Its tooth arrangement is unique: a single row in the lower jaw fits between two rows of teeth in the upper jaw. Lizards have visible ear openings but tuatara do not.



**Distribution** About 400 *Sphenodon guntheri* live on North Brother Island, New Zealand. More than 60,000 *S. punctatus* live on some 30 islands off the northeast coast of New Zealand's North Island



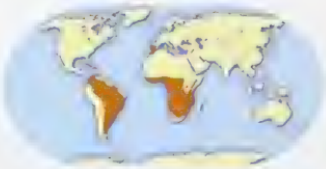

Tuatara
*Sphenodon punctatus*

**Tuatara** The name Tuatara is from Maori, meaning "peaks on the back," referring to the dorsal crest. Tuatara keep growing until they are 35 years old, and may live for more than 100 years. Sex is determined by temperature at the time of incubation

# AMPHISBAENIANS

CLASS Reptilia
ORDER Squamata
SUBORDER Amphisbaenia
FAMILIES 4
GENERA 21
SPECIES 140

These legless squamates have reduced pectoral and pelvic girdles. They have an annulated pattern of scutes, and short tails. Amphisbaenians are built for burrowing, with heavily ossified skulls. Their brain is surrounded by the frontal bones. The right lung of amphisbaenians is reduced in size, while in other limbless lizards and snakes the left lung is smaller. Three of the four families of worm lizards have no limbs whatsoever, while the remaining family has enlarged forelimbs, which help it with locomotion and digging.



**Distribution** Amphisbaenians are found in tropical and subtropical regions of southern North America, South America to Patagonia, West Indies, Africa, the Iberian Penisula, Arabia, and western Asia.

**Shovel-snouted worm lizard** The illustration below shows how the worm lizard pushes its head against the ceiling of the tunnel to widen it. Worm lizards have large, interlocking upper and lower teeth, which allow them to grasp prey and drag it into their tunnel

**Two-headed legless lizard** Amphisbaenians are often erroneously called two-headed snakes, as the tail is designed to mimic the head to confuse potential predators. A wound to the tail would be easier to survive than one to the head

**HOW THEY BURROW**

The rings of scales behind the head are close together at the start of the stroke. During penetration the rings separate, pushing the head forward. To widen the tunnel, the head is lifted against the ceiling of the tunnel.

# LIZARDS

**CLASS** Reptilia
**ORDER** Squamata
**SUBORDER** Sauria
**FAMILIES** 27
**GENERA** 442
**SPECIES** 4,560

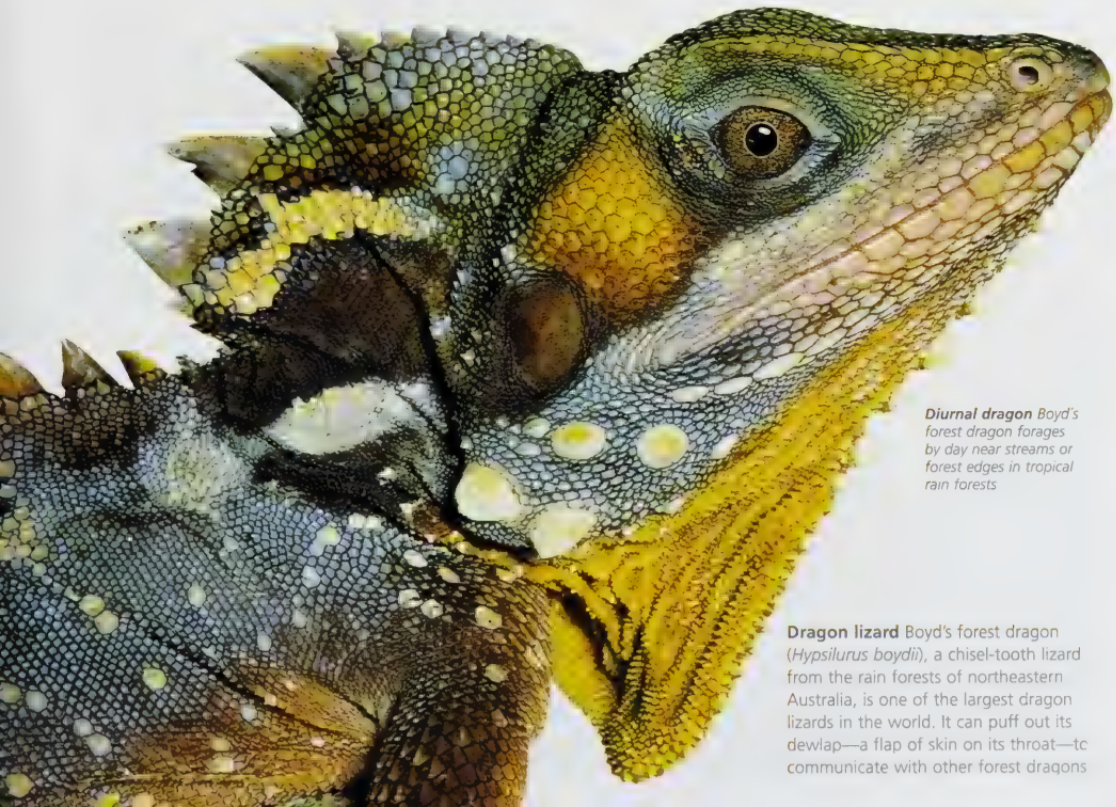
Today, lizards occupy almost all landmasses except for Antarctica and some Arctic regions. At the end of the Cretaceous period, some 65 million years ago, lizards survived when the dinosaurs and other large reptiles died out. With more than 4,000 species, they are the largest group of living reptiles. Although the largest lizard, the Komodo dragon, reaches an impressive length of 10 feet (3 m), few lizards exceed 12 inches (30 cm) and this is one reason for their continued success. Lizards tend to be restricted to specific habitat niches, as mountains and water are significant barriers to their movement.

**Distribution** Lizards are found from New Zealand to Norway, and from southern Canada to Tierra del Fuego. They are also endemic to many islands in the world's oceans. The only continent they have not colonized is Antarctica

**Territorial defense** A defined territory provides an area in which an adult male lizard can hunt for food and find a female for mating. If a rival invades its territory, a collard lizard does a series of "push-ups" to make itself look bigger and more threatening to the unwelcome interloper.

**Prehensile-tailed skink** The Solomon Island skink (*Corucia zebrata*) is arboreal and herbivorous. It uses its prehensile tail to hold onto branches as it feeds on fruits and leaves in the treetops

***Lizard features*** *The cone-like spines on the crest of the forest dragon make it appear to be larger and more formidable than it actually is, and its multicolored scales provide perfect camouflage in the mottled forest light*



***Diurnal dragon*** *Boyd's forest dragon forages by day near streams or forest edges in tropical rain forests*

**Dragon lizard** Boyd's forest dragon (*Hypsilurus boydii*), a chisel-tooth lizard from the rain forests of northeastern Australia, is one of the largest dragon lizards in the world. It can puff out its dewlap—a flap of skin on its throat—to communicate with other forest dragons

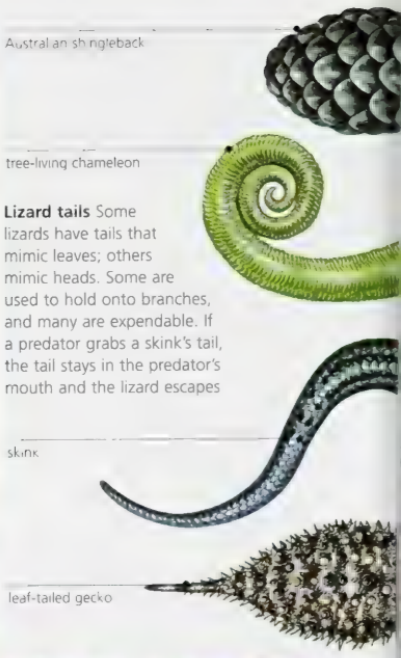
## DEFENSE AND ESCAPE

Lizards are preyed upon by spiders, scorpions, other lizards, snakes, birds, and mammals. The Gila monster and the Mexican beaded lizard are the only two venomous species, but even these will resort to scare tactics at the start of a confrontation. Many others have developed an impressive array of tactics to defend themselves or to escape an attacker.

Most lizards are extremely well camouflaged and may keep absolutely still until a predator passes by. Chameleons, in particular, are well known for their ability to change color to blend in with their environment. Other lizards surprise or distract a predator to give themselves a chance to escape. The Australian frilled lizard, for example, opens its mouth, hisses loudly, and flourishes its neck frill before scampering away.

Some species have sharp spines that can injure a predator's mouth, or slippery scales that make them hard to grip. The armadillo girdle-tailed lizard curls itself into a ball and protects itself with a prickly fence of spikes, while the basilisk escapes by skittering on water before diving to safety.

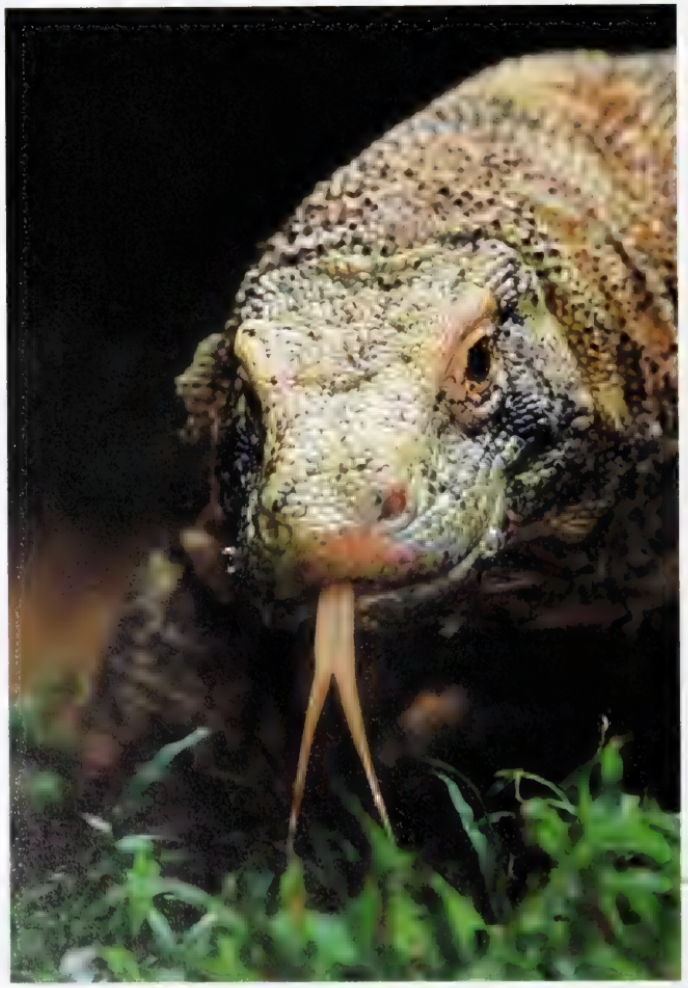
**Underwater grazers** Marine iguanas on the Galapagos Islands are herbivores from the time they hatch. They dive into the ocean to forage on algae. Before and after diving, they bask to increase their body temperatures to help them more efficiently digest their food, and also to increase swimming stamina in the usually cold seas

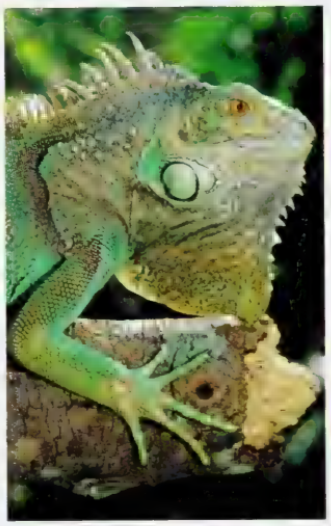



**Lizard tails** Some lizards have tails that mimic leaves; others mimic heads. Some are used to hold onto branches, and many are expendable. If a predator grabs a skink's tail, the tail stays in the predator's mouth and the lizard escapes

Lizards use their tails for defense. Monitors and iguanas beat their attackers with their tails. Skinks and other small lizards may give up a little piece of tail in return for their lives. These lizards often have brightly colored tails that they will wave from side to side, inducing the predator to attack the tail and not the head. The tail continues to wriggle after the lizard has escaped. Shed tails grow back after time; the lizard loses some stored energy but remains alive to reproduce. In territorial bouts, some geckos attack and eat the tails of their opponents.

Horned lizards, when attacked by foxes and coyotes, will squirt a stream of bad-tasting blood out of their eyes to distract and discourage predatory predators. Some lizards also attempt to scare off predators by stretching out their tongues. Australian skinks hiss and thrust their brightly colored tongues out to look poisonous. Even though the tongues represent a consistent and brightly colored target for most predators of the sort of lizards they eat, if predated it will direct its bright purple tongue and hiss at its aggressor.





**Rain-forest ranch** The common green iguana (above) is completely herbivorous after hatching. The low-cholesterol meat is eaten as a delicacy in Meso-America

**Predatory dragon** The Indonesian Komodo dragon (left) tests the air for the scent of warm-blooded prey. These lizards grow to be more than 10 feet (3 m) in total length and feed on large mammals such as deer, pigs, goats, and even water buffalo

Fiji banded iguana
*Brachylophus fasciatus*, family Iguanidae

West Indian iguana
*Iguana delicatissima*, family Iguanidae

Marine iguana
*Amblyrhynchus cristatus*, family Iguanidae

Galápagos land iguana
*Conolophus subcristatus*, family Iguanidae

Rhinoceros iguana
*Cyclura cornuta*, family Iguanidae

Black iguana
*Ctenosaura similis*, family Iguanidae

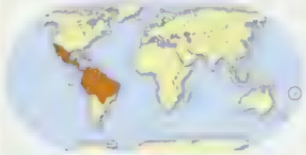
The warmer male black iguana (top) is lighter in color; the other male is colder and darker

Green iguana
*Iguana iguana*, family Iguanidae

## FACT FILE

**Family Iguanidae** This family contains terrestrial, rock-dwelling, marine, and arboreal species. They range from the 5½ inch (14 cm) snout–vent length *Dipsosaurus* to the more than 27½ inch (70 cm) *Cyclura*. Young iguanas of some species eat insects, but later become predominantly herbivorous, feeding on leaves, fruit, and even algae. All species are oviparous

**Genera** 8
**Species** 36



USA to Paraguay, Galápagos Is., Fiji, West Indies

***Old salts***
*Marine iguanas spend so much time at sea that they have a special gland to exude salt from their bodies*

***Long time coming***
*The Fiji crested iguana (Brachylophus vitiensis) has a 30-week incubation—three times that of other iguanas.*

## LIZARD TONGUES

The long forked tongues of monitors are used to capture scent information from the air and to transfer it to the Jacobson's organ for analysis. The long, sticky tongues of chameleons are used to capture prey, while the blue-tongued skink (below) flashes its tongue to deter attacking birds

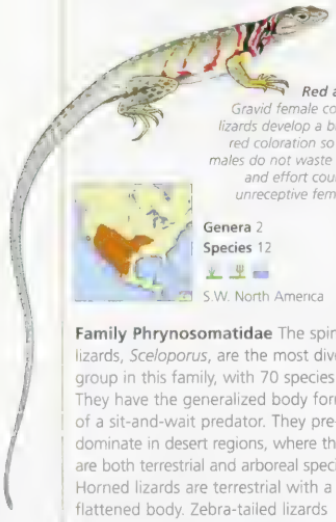
## CONSERVATION WATCH

The 15 species of iguanas on the IUCN Red List are categorized as follows

- 5 Critically endangered
- 2 Endangered
- 7 Vulnerable
- 1 Near Threatened

## FACT FILE

**Family Crotaphytidae** Collard and leopard lizards are medium-length diurnal lizards active in deserts and other rocky, arid areas. They feed on invertebrates, lizards, and other small vertebrates. They employ squealing vocalizations when stressed, and can use a form of bipedalism when moving among rocks. They are oviparous, laying three to eight eggs per clutch



***Red alert*** *Gravid female collard lizards develop a bright red coloration so that males do not waste time and effort courting unreceptive females*



**Genera** 2
**Species** 12
S.W. North America

**Family Phrynosomatidae** The spiny lizards, *Sceloporus*, are the most diverse group in this family, with 70 species They have the generalized body form of a sit-and-wait predator. They predominate in desert regions, where there are both terrestrial and arboreal species Horned lizards are terrestrial with a flattened body. Zebra-tailed lizards are a rapid bipedal desert lizard

***Defensive spines*** *The regal horned lizard has the largest crown of spines of any species These are effective in avoiding predation by many species of snakes*

**Genera** 9
**Species** 110
Southern Canada & USA to Panama

## CONSERVATION WATCH

**Lizard losses** One species of Crotaphytidae, the blunt-nosed leopard lizard (*Gambelia sila*), is listed as endangered on the IUCN Red List due to habitat encroachment. One species of Phrynosomatidae, the Coachella Valley fringe-toed lizard (*Uma inornata*) of North America, is on the IUCN Red List as endangered. It lives in moving dune areas which have now been stabilized by vege- [illegible] on and construction. Populations [illegible] llard and leopard lizards, how- [illegible] are abundant in the southwest [illegible] United States.

Merrem's Madagascar swift
*Oplurus cyclurus*, family Opluridae

Collard lizard
*Crotaphytus collaris*, family Crotaphytidae

Side-blotched lizard
*Uta stansburiana*, family Phrynosomatidae

Chuckwala
*Sauromalus obesus*, family Phrynosomatidae

Leopard lizard
*Gambelia sila*, family Crotaphytidae

Regal horned lizard
*Phrynosoma solare*, family Phrynosomatidae

Short-horned lizard
*Phrynosoma douglass*, family Phrynosomatidae

Desert spiny lizard
*Sceloporus magister*, family Phrynosomatidae

Colorado desert fringe-toed lizard
[illegible] *notata*, family Phrynosomatidae

Blue-throated anole
*Norops nitens*, family Polychrotidae

Male giving compound courtship display

Green basilisk lizard
*Basiliscus plumifrons*, family Corytophanidae

Only males have a head crest

Banded tree anole
*Anolis transversalis*, family Polychrotidae

Knight anole
*Anolis equestris*, family Polychrotidae

Vinales anole
*Anolis vermiculatus*, family Polychrotidae

Bearded anole
*Anolis barbatus*, family Polychrotidae

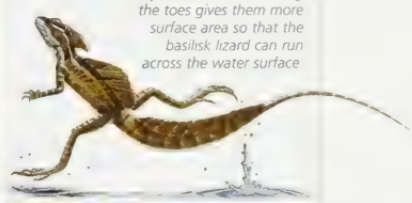
Green thornytail iguana
*Uracentron azureum*, family Tropiduridae

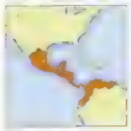
Common monkey lizard
*Polychrus marmoratus*, family Polychrotidae

## FACT FILE

**Family Corytophanidae** All members of this family are carnivorous. Crested lizards are arboreal, living in rain forests or tropical scrub forests. Up to 8 inches (20 cm) in snout–vent length, they have a casque-shaped head, slender body, long legs, and long tails. Basilisk lizards forage mainly on the ground, returning to the trees for escape.

***No problem*** *Lamina along the toes gives them more surface area so that the basilisk lizard can run across the water surface*

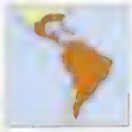




**Genera** 3
**Species** 9
Mexico to Colombia, Venezuela

**Family Polychrotidae** All anoles have subdigital lamellae for climbing and a colorful dewlap for intraspecific communication. Some species are terrestrial, others are aquatic. Many are arboreal. All will lose their tails if they are grasped, and are oviparous, laying one to two eggs per clutch. Most are entirely carnivorous.

***Territorial display*** *Male anoles have a gular fold, or dewlap, that they inflate to show their attraction for females and to maintain distance between males*



**Genera** 8
**Species** 395
Central and South America, Caribbean, USA

## CONSERVATION WATCH

In general, the diverse habitat needs of basilisks and anoles ensure abundant populations throughout much of their ranges. However, studies are lacking on many of the species endemic to rain forests in Mexico and Central America. As these habitats dwindle, populations may need protection. The four species of Polychrotidae on the IUCN Red List are categorized as follows:

1 Critically endangered
1 Vulnerable
2 Data deficient

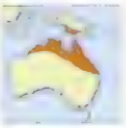
## FACT FILE

**Family Agamidae** Chisel-tooth lizards are from Africa, Asia, and Australia. There are 52 genera, ranging from 2 to 14 inches (5 to 35 cm) in length from snout to vent. Forest species are green; desert species are brown, gray, or black. Sexual dimorphism in coloration is common; some can change coloration rapidly. The head is usually large, and distinct from the neck; the body form may be compressed, depressed, or cylindrical. The thick tongue is notched.

**Genera** 50
**Species** 420

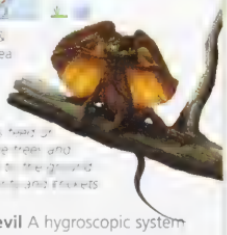
Australia, Indonesia, Asia, Africa

**Frilled lizard** This arboreal lizard is active diurnally in dry woodlands. When escaping, it runs bipedally. If threatened, it erects its huge frilled collar to appear much larger than it is.



Up to 11¼ in (28 cm)
Arboreal
Oviparous
8–23
Common

N. Australia & New Guinea



*Carnivores*
Frilled lizards feed on insects in the tree and on the ground. They also eat birds and rodents.

**Thorny devil** A hygroscopic system of grooves on this lizard's skin leads to the corners of its mouth, allowing it to drink the dew that falls on its back. It feeds only on ants, similar to the North American horned lizard.

## CONSERVATION WATCH

The five species of Agamidae on the 2003 IUCN Red List are categorized as follows:

- Endangered
- Vulnerable
- Data deficient

1 Frilled lizard
*Chlamydosaurus kingii*, family Agamidae

2 Banded agama
*Laudakia stellio*, family Agamidae

3 Thorny devil
*Moloch horridus*, family Agamidae

4 Eastern bearded dragon
*Pogona barbata*, family Agamidae

5 Ocellated mastigure
*Uromastyx ocellata*, family Agamidae

6 Sinai agama
*Pseudotrapelus sinaitus*, family Agamidae

7 Iranian toad-headed agama
*Phrynocephalus persicus*, family Agamidae

8 Persian agama
*Trapelus persicus*, family Agamidae

9 Moroccan dabb lizard
*Uromastyx acanthinura*, family Agamidae

10 Common agama
*Agama agama*, family Agamidae

1 Armored pricklenape
*Acanthosaura armata*, family Agamidae

2 Five-lined flying dragon
*Draco quinquefasciatus*, family Agamidae

3 Sailfin lizard
*Hydrosaurus amboinensis*, family Agamidae

4 Giant forest dragon
*Gonocephalus grandis*, family Agamidae

5 Chinese water dragon
*Physignathus cocincinus*, family Agamidae

6 Sumatra nose-horned lizard
*Harpesaurus beccarii*, family Agamidae

7 Indo-Chinese forest lizard
*Calotes mystaceus*, family Agamidae

8 Common green forest lizard
*Calotes calotes*, family Agamidae

9 Tropical forest dragon
*Gonocephalus liogaster*, family Agamidae

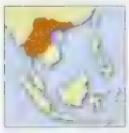
## FACT FILE

**Sailfin lizard** This semiaquatic lizard forages and basks along the edges of streams. When danger approaches, it runs bipedally across the surface of the water with the aid of a fringe on the toes of its hindlimbs. Populations are declining due to over-collection for the pet trade and its popularity as food

Up to 40 in (100 cm)
Variable
Oviparous
6–12
Common

S.E. Asia, New Guinea

**Chinese water dragon** These lizards are semiaquatic, living along the shores of rivers, climbing into the lower branches of trees, and sharing burrows in colonies of one dominant male and several females. Males have larger crests than females. Incubation time for water dragon eggs is 60 days.



Up to 12 in (30 cm)
Variable
Oviparous
7–12
Common

Thailand, E. Indochina, Vietnam, S. China

**Common green forest lizard** This arboreal lizard inhabits most forest areas to an altitude of 4,900 feet (1,500 m), beyond which they are replaced by other species. Males, the largest lizards in Sri Lanka, have very vivid coloration.

Up to 12 in (30 cm)
Arboreal
Oviparous
10–20
Common

India & Sri Lanka

## TREE DRAGON

The semiarboreal tree dragon (*Dipo-riphora superba*) is one of the most slender agamids. It measures 3 inches (8 cm) in snout–vent length and its tail is up to four times its body length

***Treetop maneuvers***
*The tree dragon [illegible] tail for bal[illegible]*

# LIZARD REPRODUCTION

Reproductive patterns in lizards vary widely. Some lizard species mature rapidly, are short lived, and are continuously producing an egg. Other species take several years to mature and then lay large clutches of large eggs for many years. Between these two extremes there are all possible variations of numbers of clutches per year and viviparity. Some species are egg layers at low altitudes but populations at high altitudes or latitudes are viviparous. The female acts as an incubator, moving with the developing embryos into optimum incubation temperatures. Equally amazing are some species that are stuck in evolutionary inertia and produce no more than two eggs per clutch regardless of their size or the amount of stored energy.

**Clutch size** Geckos (top), regardless of size or nutrient condition, produce two eggs per clutch. Some species can vary clutch size and egg size (center). Large species (bottom) have large clutches of large eggs and the number and size of the eggs is proportionate to the size and physical condition of the female

**Skink with eggs** Many species of skinks and glass lizards brood their eggs. The female stays with them, helping to fend off attacks from insect predators, and protecting them from fungus and dehydration until they hatch. Some skinks even lick their young as they are hatching

**Continuous ovulation** Anoles of all sizes only produce one egg per clutch; they have continuous ovulation, first from one ovary then the other.

**Sceloporus with eggs** Fence lizards (Sceloporus) are able to vary the number and [illegible] of year and their physical condition. They [illegible] smaller eggs for [illegible] develop before the onset of winter.

**Iguana with eggs** Iguanas normally dig tunnels in sandy beaches and deposit between 25 and 40 eggs, depending on the size of the female. The eggs hatch in 3 months and the hatchlings seek out other iguanas in order to eat their feces, thereby inoculating their guts with cellulose-digesting microbes

Knysna dwarf chameleon is ovoviviparous, having up to two litters of 6–20 young after a gestation period of 4–6 months

Female giant Madagascar chameleons are only half the size of males; lay up to 61 eggs per clutch and are mature within a year

1 Knysna dwarf chameleon
*Bradypodion damaranum*, family Chamaeleonidae

2 Common Mediterranean chameleon
*Chamaeleo chamaeleon*, family Chamaeleonidae

3 Malthe's elephant-eared chameleon
*Calumma malthe*, family Chamaeleonidae

4 Jackson's chameleon
*Chamaeleo jacksonii*, family Chamaeleonidae

5 Carpet chameleon
*Furcifer lateralis*, family Chamaeleonidae

6 Giant Madagascar chameleon
*Furcifer oustaleti*, family Chamaeleonidae

7 Lesser chameleon
*Furcifer minor*, family Chamaeleonidae

8 Parson's chameleon
*Calumma parsoni*, family Chamaeleonidae

9 Horned leaf chameleon
*Brookesia superciliaris*, family Chamaeleonidae

## FACT FILE

**Family Chamaeleonidae** Chameleons are famous for their ability to change colors. Their tail is prehensile and two or three of their toes are fused to form grasping pads. Their eyes can move independently and they have three-dimensional vision when they look ahead. This allows them to focus on the prey in front of them. Their tongue is elongated, allowing them to catch prey at a distance of one body length. They grow up to 25¼ inches (63 cm) long and are largely terrestrial

**Genera** 6
**Species** 135

Africa, Madagascar, S. Europe, Middle East, India & Sri Lanka

***Splitting out of their skin***
*The Mediterranean chameleon sheds its skin all at once. Lizards need to shed their skin in order to grow*

**Giant Madagascar chameleon** This species inhabits warm, humid coastal lowlands as well as drier forests. It has a high casque without occipital lobes, horns, or rostral processes. Gular and dorsal crests are composed of specialized, prominent conical scales. Males are larger and have broader tail bases than females.

Madagascar

- Up to 24 in (60 cm)
- Arboreal
- Oviparous
- 1–61
- Common

## CONSERVATION WATCH

Habitat loss is the prime reason for the decline in chameleon numbers. But they are also threatened by the pet trade: from 1993 to 1998, 476,000 chameleons were exported from Africa, Yemen, the Seychelles, and Madagascar. The eight species of chameleons on the IUCN Red List are categorized as follows:

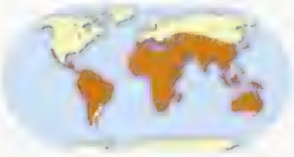
- 1 Critically endangered
- 1 Endangered
- 4 Vulnerable
- 2 Near threatened

## FACT FILE

**Family Gekkonidae** The geckos are the most speciose family of lizards, split into four subfamilies. Covered with small granular scales, they vary in size from ¾ inch to 13 inches (1.5 to 33 cm). The tails are usually fragile and break easily

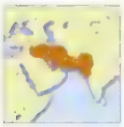
***Tongue washing*** *Most species of geckos do not have eyelids and use the tongue to clean the eye spectacles, as in Cogger's velvet gecko*

**Genera** 109
**Species** 970



Pan-tropical, S. North America, South America, Africa, S. Europe, S. Asia, Indo-Australia

**Common leopard gecko** Leopard geckos have moveable eyelids and lack toe pads. The sex is determined by incubation temperature



Up to 10 in (25 cm)
Terrestrial
Oviparous
2
Common

Afghanistan, Pakistan, W. India, Iraq, Iran

**Banded gecko** This nocturnal gecko has large, moveable eyelids, no toe pads and pre-anal pores in a continuous row. Tails are easily lost.

Up to 4 in (10 cm)
Terrestrial
Oviparous
2
Common

W. USA to Mexico & Panama

## ADAPTED FOR SAND

Fine free-flowing sand requires specialized feet to efficiently traverse the surface. The African [illegible]

***Sand shoes*** *Some lizards have fringes along [illegible]*

1 **Tokashiki gecko** *Goniurosaurus kuroiwae*, family Gekkonidae

2 **Common leopard gecko** *Eublepharis macularius*, family Gekkonidae

3 **Prehensile tailed gecko** *Aeluroscalabotes felinus*, family Gekkonidae

4 **Banded gecko** *Coleonyx variegatus*, family Gekkonidae

5 **Green tree gecko** *Naultinus elegans*, family Gekkonidae

6 **Thomas's sticky-toed gecko** *Hoplodactylus rakiurae*, family Gekkonidae

7 **New Caledonia bumpy gecko** *Rhacodactylus auriculatus*, family Gekkonidae

8 **Stellate knob-tail** *Nephrurus stellatus*, family Gekkonidae

9 **Northern leaf-tailed gecko** *Saltuarius cornutus*, family Gekkonidae

1 Lined gecko
*Gekko vittatus*, family Gekkonidae

2 Henkel's flat-tailed gecko
*Uroplatus henkeli*, family Gekkonidae

3 Tokay gecko
*Gekko gecko*, family Gekkonidae

4 Northern spiny-tailed gecko
*Diplodactylus ciliaris*, family Gekkonidae

5 Marbled velvet gecko
*Oedura marmorata*, family Gekkonidae

6 Marble-faced worm lizard
*Delma australis*, family Pygopodidae

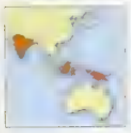
7 Burton's snake-lizard
*Lialis burtonis*, family Pygopodidae

8 Gray's bow-fingered gecko
*Cyrtodactylus pulchellus*, family Gekkonidae

9 Common wonder gecko
*Teratoscincus scincus*, family Gekkonidae

## FACT FILE

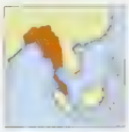
**Lined gecko** This gekko has a distinct white dorsal stripe. The tail is cross-banded. They are nocturnal and have large distinct laminae on the toes for climbing. Males have a V-shaped row of enlarged pre-anal pores and hemi-penal bulges at the base of the tail.



Up to 10 in (25 cm)
Terrestrial
Oviparous
2
Common

Indo-Australian archipelago

**Gray's bow-fingered gecko** This gecko has a flattened, compact body. The toes are long and thin, bending upward and at the ultimate phalange turning downwards, terminating with small lamellae. Granular dorsal scales become spine-like on the tail.



Up to 8 in (20 cm)
Terrestrial
Oviparous
2
Common

Central Asia, S.E. Asia

**Family Pygopodidae** This family is closely related to the geckos. Forelimbs are lacking, and the hindlimbs are represented by a scaly flap just anterior to the cloaca. Their tails are fragile and easily broken. The eyes are snake-like, as they lack lids and are covered with an immovable spectacle. Some species have external ear openings. They breed in summer and most lay two eggs. The majority are insectivorous.

***Rudimentary feet***
*The hindlimb of the Burton's snake lizard has been reduced to a flap-like scale, useful for traction in flowing sand*

**Genera** 8
**Species** 36

Australia except Tasmania
Aru Islands, New Guinea, New Britain

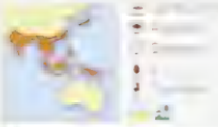
## CONSERVATION WATCH

The seven species of Pygopodidae listed on the IUCN Red List are categorized as follows:

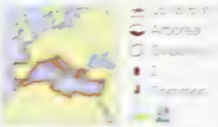
6 Vulnerable
1 Near threatened

## FACT FILE

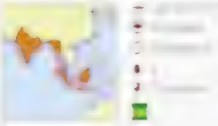
**Mourning gecko**



**Common wall gecko**




**Kuhl's flying gecko**



## FLYING GECKO

## CONSERVATION WATCH

The 27 species of Gekkonidae on the IUCN Red List are categorized as follows:

- Extinct
- Critically endangered
- Endangered
- Vulnerable
- Near threatened
- Data deficient
- Least concern

Broad-tailed day gecko is native to Madagascar but is well established on Hawaii.

1 **Madagascar day gecko**
*Phelsuma madagascariensis*, family Gekkonidae

2 **Broad-tailed day gecko**
*Hemiphyllodactylus typus*, family Gekkonidae

3 **Mourning gecko**
*Lepidodactylus lugubris*, family Gekkonidae

4 **Common wall gecko**
*Tarentola mauritanica*, family Gekkonidae

5 **Israeli fan-fingered gecko**
*Ptyodactylus puteum*, family Gekkonidae

6 **Kuhl's flying gecko**
*Ptychozoon kuhli*, family Gekkonidae

7 **Anderson's short-fingered gecko**
*Stenodactylus petrii*, family Gekkonidae

8 **Ruppell's leaf-toed gecko**
*Hemidactylus flaviviridis*, family Gekkonidae

9 **Cradock thick-toed gecko**
*Pachydactylus geitje*, family Gekkonidae

10 **Wiegmann's striped gecko**
*Gonatodes vittatus*, family Gekkonidae

1 Rough-scaled plated lizard
Gerrhosaurus major
family Gerrhosauridae

2 Madagascar girdled lizard
Zonosaurus madagascariensis
family Gerrhosauridae

3 Long-tail whip lizard
Teratoscincus microlepis
family Gerrhosauridae

4 Lesser flat lizard
Platysaurus lineatus, family Cordylidae

5 Karoo girdled lizard
Cordylus polyzonus, family Cordylidae

6 Black crag lizard
Pseudocordylus melanotus
family Cordylidae

7 Moto skink
Mabuya spilogaster, family Scincidae

8 Schneider's skink
Chalcides ocellatus, family Scincidae

9 Sand fish
Scincus scincus, family Scincidae

## FACT FILE

Family Gerrhosauridae

Swimming through grass

Genera
Species

Family Cordylidae

Genera
Species

Defensive behavior

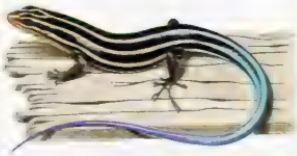
## CONSERVATION WATCH

## FACT FILE

**Family Scincidae** [illegible]

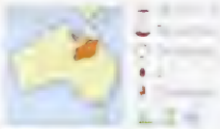
Genera [illegible]
Species [illegible]

[illegible]



**Tetrale tails** [illegible]

**Hosmer's spiny-tailed skink** [illegible]



[illegible]

**Centralian blue-tongued lizard** [illegible]

[illegible]

1 Solomon Island skink
[illegible]

2 Emerald skink
[illegible]

3 Hosmer's spiny-tailed skink
[illegible]

4 Centralian blue-tongued lizard
[illegible]

5 Shingleback lizard
*Tiliqua rugosa*, family Scincidae

6 Three-lined burrowing skink
*Androngo trivittatus*, family Scincidae

7 Otago skink
*Oligosoma otagense*, family Scincidae

1 **Bridled mabuya**
*Mabuya vittata*, family Scincidae

2 **Christmas Island grass skink**
*Lygosoma bowringii*, family Scincidae

3 **Boulenger's legless skink**
*Typhlosaurus vermis*, family Scincidae

4 **Red-sided ctenotus**
*Ctenotus pulchellus*, family Scincidae

5 **Northwestern sandslider**
*Lerista bipes*, family Scincidae

6 **Cape York mulch skink**
*Glaphyromorphus crassicaudum*, family Scincidae

7 **Lined fire-tailed skink**
*Morethia ruficauda*, family Scincidae

8 **Juniper skink**
*Ablepharus kitaibelii*, family Scincidae

9 **Desert rainbow skink**
*Carinatriacantna*, family Scincidae

10 **Six-lined burrowing skink**
*Scelotes sexlineatus*, family Scincidae

## FACT FILE

**Northwestern sandslider** This lizard slides through sand without any front limbs; the hindlimbs are reduced and have only two digits. It is found on both sandy plains and coastal dunes.

N.W. Australia

**Cape York mulch skink** This smooth-scaled skink lives in forest and coastal dune communities where it forages under logs, stones, or in leaf litter.

N.E. Australia

**Desert rainbow skink** This diurnal lizard has a transparent disk in the movable lower eyelid and a circular ear opening. It forages in the leaf litter.

N.W. Australia

## AUSTRALIAN BLUE TONGUE PYGMY SKINK

*Miloua adelaidensis* was thought to be extinct, but in 1990 one was found in a snake's stomach. Since that time, a recovery plan has been in operation and numbers have now reached 5,500.

## CONSERVATION WATCH

The 43 species of Scincidae on the IUCN Red List are categorized as follows:

- 3 Extinct
- 2 Critically endangered
- 3 Endangered
- 21 Vulnerable
- 5 Near threatened
- 7 Data deficient
- 2 Least concern

# LIZARD COURTSHIP

Courtship displays have evolved in lizards to ensure that gametes are not wasted on mating with the wrong species or inferior individuals. Males often maintain territories in resource-rich areas and will fight other males to maintain them. Females are allowed to enter males' territories and are encouraged to mate by energetic courtship displays. When there are many similar species or species in the same genus in the same habitat the courtship behavioral patterns are more complex. Courtship displays are most complex and have been most intensively studied in the family Polychrotidae. Courtship in monitor lizards (Varanidae) involves tongue flicks by males along different parts of the female's body during the initiation of courtship. Communication in skinks is primarily chemical.

**Anole courtship displays** Small insectivorous lizards are most adapted to using visual communication for courtship. The males have species-specific, bright dewlap colors and head bobs, push-ups, or other motions that attract females to them for copulation. Variation exists between individuals, so that females can select a male by the way he courts her. The male's vigor in courtship is the component most often used by females in their selection of a mate.

***Bobbing rapidly*** *The carpenter anole Norops carpenteri (above) has a simple display, the dewlap, which is uniformly orange-colored, is extended and held open, while the head is bobbed at regular frequency. The male has a series of over a dozen rapid head bobs in his courtship display, while holding his dewlap extended the entire time.*

***Variable bobbing*** *The red-throat anole N. sericeus (above) has a complex display; the dewlap has a central yellow blotch with the blue color. When the dewlap is extended, they eventually, the color appears pink. The head bob pattern is independent of the dewlap extension motion. The male begins bobbing rapidly for the first few bobs, then pauses, then motion for the duration of the display, the dewlap is extended and bobbing ceases.*

***Wave bobbing*** *[illegible]*

**Pseudo-copulation** In the whiptails (Cnemidophorus) of the southwestern deserts of the United States, females reproduce without males or their sperm (parthenogenetic reproduction). The genetic component of the female is identical to that of her offspring. Pseudo-copulation occurs in some species of these clones of all female lizards. One female behaves like a male and attempts to mount with another female. The courtship and pseudo-copulation stimulate ovulation.

***Larger than life*** *By expanding its folded neck skin, the frilled dragon can appear much larger when threatening other males or attempting to attract females*

***Larger than life*** *When the frill is extended fully, it can reach 14 inches (35 cm) across, longer than its body length.*

***Rain-maker*** *[illegible]*

**Expanding frill** Dominant male frilled lizards show off different display sequences during courtship of females or territoriality displays toward other males. Over 75 different sequences have been recorded, including head bobbing, push-ups, beard erection, color changes, body inflations, head licking, and jaw gaping. Apart from the changes in shape and size of the lizard, changes in color and flashes of color as they open the mouth are a major part of their repertoire.

1 **European green lizard**
*Ablepharus kitaibelii*, family Lacertidae

2 **Giant Canary Island lizard**
*Gallotia stehlini*, family Lacertidae

3 **Zagrosian lizard**
*Timon princeps*, family Lacertidae

4 **Tiger lizard**
*Nucras tessellata*, family Lacertidae

5 **Jeweled lizard**
*Timon lepidus*, family Lacertidae

6 **Sand lizard**
*Lacerta agilis*, family Lacertidae

7 **Gallot's lizard**
*Gallotia gallot*, family Lacertidae

8 **Balkan emerald lizard**
*Lacerta trilineata*, family Lacertidae

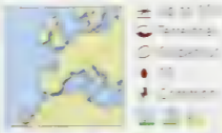
## FACT FILE

**Family Lacertidae** Adult lacertids are 3½–18 inches (8–45 cm) in total length. The sexes are variable, from large, sexually dimorphic or reduced to small and granular. All lacertids have limbs. Tails are long, sometimes over twice the body length. Most lacertids are terrestrial, but some are arboreal. Most are oviparous, but some are viviparous and some populations are parthenogenetic. Almost all species are insectivorous and some eat seeds.

**Genera** 27
**Species** 220

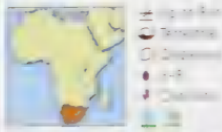
Africa, Europe, Asia & N. West India

**Giant Canary Island lizard** Hatchlings take 3 years to reach maturity and live for about 10 years. Adults are primarily herbivorous and are important in seed dispersal. The disproportionately long hindlimbs of males allow them faster acceleration when escaping predators.



Grand Canaria Island, Canaries

**Tiger lizard** These lizards actively hunt scorpions, which are dormant during the day and sparsely distributed, which makes them easy targets for predatory birds. Tiger lizards avoid predation by being active during the heat of the day at a body temperature of 100°F (38°C).



S. Namibia, S. to E. Botswana, South Africa

## CONSERVATION WATCH

The 13 species of Lacertidae in the IUCN Red List are classified as follows:

1. [illegible]
2. [illegible]
3. [illegible]
4. [illegible]
5. [illegible]
6. [illegible]

## FACT FILE

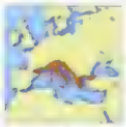
**Family Xantusiidae** Even though [illegible] are called night lizards many species are diurnal. They are small lizards, up to 4 inches (10 cm) long, with small granular dorsal scales and large ventral scales. All species are viviparous. Most species feed on invertebrates, although one cave-dwelling species feeds on figs. Night lizards are terrestrial and arboreal. In Mexico, Lepidophyma, a species of night lizard, are called scorpions and are mistakenly thought to be venomous. Like many lizards, their tails will break off if grasped; a new tail will regenerate but will be of a uniform color.

***Liberated from males*** The yellow-spotted night lizard Lepidophyma flavimaculatum [illegible] and viviparous. Some populations are parthenogenetic.

**Genera** 3
**Species** 20

W. USA & E. Mexico, Central America & N. South America

**Common wall lizard** This is a colonial species. It is a good climber and basks on rocks. Wall lizards feed on invertebrates, beetles, flies, butterflies, and spiders. They are prey items for raptors and snakes, particularly young horned vipers or large whip snakes.



Up to 4 in (10 cm)
Terrestrial, arboreal
Oviparous
[illegible]
[illegible]

Southern Europe & Balkans

## CONSERVATION WATCH

**Restricted range** One species of Xantusiidae, the North American island night lizard (*Xantusia riversiana*), is listed on the IUCN Red List as vulnerable. The distribution of this lizard is restricted to San Clemente, Santa Barbara, and the San Nicholas Islands off the coast of southern California, United States. This habitat grasslands, cactus [illegible], cliffs, and rocky beaches. This species is vulnerable because of [illegible] population and development of its island habitats.

1 Italian wall lizard
*Podarcis sicula*, family Lacertidae

2 Common wall lizard
*Podarcis muralis*, family Lacertidae

3 Menorca wall lizard
[illegible]*ita*, family Lacertidae

4 Desert night lizard
*Xantusia vigilis*, family Xantusiidae

5 Granite night lizard
*Xantusia henshawi*, family Xantusiidae

6 Viviporus lizard
*Lacerta vivipara*, family Xantusiidae

7 Radd's rock lizard
*Lacerta raddei*, family Xantusiidae

8 Uzzell's rock lizard
*Lacerta uzzeli*, family Xantusiidae

9 Milo's wall lizard
*Podarcis milensis*, family Xantusiidae

1 **Egyptian fringe-fingered lizard**
*Acanthodactylus pardalis*,
family Lacertidae

2 **Rapid racerunner**
*Eremias velox*, family Lacertidae

3 **Algerian psammodromus**
*Psammodromus algirus*,
family Lacertidae

4 **Blue-throated keeled-lizard**
*Algyroides nigropunctatus*,
family Lacertidae

5 **Small-spotted lizard**
*Mesalina guttulata*, family Lacertidae

6 **Asian grass lizard**
*Takydromus sexlineatus*,
family Lacertidae

7 **Sawtail lizard**
*Holaspis guentheri*, family Lacertidae

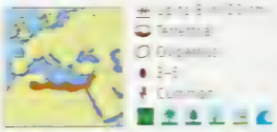
8 **Mourning racerunner**
*Heliobolus lugubris*, family Lacertidae

9 **Slender sand lizard**
*Meroles anchietae*, family Lacertidae

10 **Snake-eyed lizard**
*Ophisops elegans*, family [illegible]

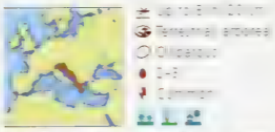
## FACT FILE

**Egyptian fringe-fingered lizard** The toes on these lizards have a fringe enabling better traction over windblown sand dunes. They also have prolonged nostrils and countersunk lower jaws to allow them ease in plowing through sand. Ants make up most of their diet.



Algeria, Egypt, Israel, Jordan, Arabia

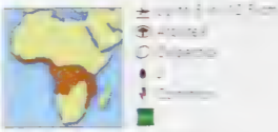
**Blue-throated keeled-lizard** These diurnal lizards are the smallest lacertids in Europe, and forage for insects in vineyards and buildings. They emerge from hibernation and breed in April; breeding males have a bright blue throat and orange-red ventral surface.



N.E. Italy to Gulf of Corinth & Ionian Islands

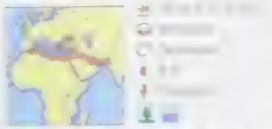
**Sawtail lizard** Its flattened shape and striking coloration make this species unmistakable. This lizard uses its flat body and broad tail to glide through the air from tree to tree. They have long, stout trunks and tails and relatively strong hindlimbs.

*Long jumper*
The sawtail lizard jumps up to 17 feet (5 m) from tree to tree. Its flattened body and tail assisting the feat.



C., E. & W. Africa, Madagascar

**Snake-eyed lizard** [illegible] look to [illegible]



## FACT FILE

**Family Gymnophthalmidae** [illegible]

Genera 36
Species 160

**Family Teiidae** [illegible] lizards and tegus. Almost all are oviparous. Varies in adult size from 2 to 16 inches (5 to 40 cm) in snout-vent length. Dorsal and lateral scales are small and granular while the ventral scales are larger, rectangular and in rows. The tails are long and autonomic. Smaller whiptails prefer deserts, grasslands, and open areas in the forest where they prey on invertebrates. The larger tegus prefer open forest and are omnivorous.

*Sexless clones*
[illegible]

Genera [illegible]
Species [illegible]

**Golden tegu** [illegible]

## CONSERVATION WATCH

The six species of Teiidae on the IUCN Red List are categorized as follows:

- Extinct
- Critically endangered
- [illegible]
- Data deficient

1 **Ocellated tegu**
*Ameiva ocellata*, family Gymnophthalmidae

2 **Thomas's bachia**
*Bachia panoplia*, family Gymnophthalmidae

3 **Two-ridged neusticurus**
*Neusticurus bicarinatus*, family Gymnophthalmidae

4 **Rainbow lizard**
*Cnemidophorus lemniscatus*, family Teiidae

5 **Green calango**
*Kentropyx calcarata*, family Teiidae

6 **Four-toed tegu**
*Tupinambis teyou*, family Teiidae

7 **Slow worm**
*Anguis fragilis*, family Anguidae

8 **Common worm lizard**
*Ophiodes intermedius*, family Anguidae

9 **Southern alligator lizard**
*Elgaria multicarinata*, family Anguidae

Lives in the low branches of trees above the water; the tail is high and flattened dorso-laterally for swimming

1 **Giant ameiva**
*Ameiva ameiva*, family Teiidae

2 **Banded galliwasp**
*Diploglossus fasciatus*, family Anguidae

3 **Chinese crocodile lizard**
*Shinisaurus crocodilurus*, family Xenosauridae

4 **Golden tegu**
*Tupinambis teguixin*, family Teiidae

5 **European glass lizard**
*Pseudopus apodus*, family Anguidae

6 **Slender glass lizard**
*Ophisaurus attenuatus* family Xenosauridae

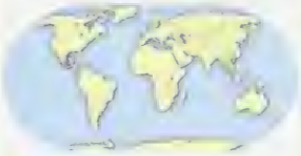
7 **Crocodile tegu**
*Crocodilurus lacertinus*, family Teiidae

8 **Paraguay Caiman lizard**
*Dracaena paraguayensis*

## FACT FILE

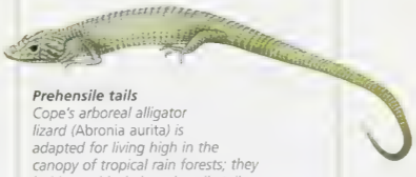
**Family Xenosauridae** The xenosaurian or knob-scaled lizards are covered with granular scales and large tubercules These insectivorous lizards inhabit mountainous tropical rain forests in southern Mexico and Guatemala, where they live in rock crevices or tree holes. The Chinese crocodile lizard, their widely disjunct relative, forages for fishes and tadpoles in mountain streams.

**Genera** 2
**Species** 5



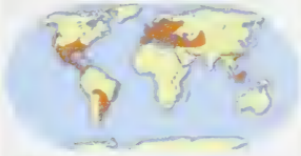
S. China & S. Mexico & Guatemala

**Family Anguidae** Anguids have heavily armored scales with underlying osteoderms. Most have limbs, but a large number of them are limbless with long tails that are two-thirds of their total length. They are commonly called glass snakes, because when attacked by a predator the tail breaks into several pieces.



***Prehensile tails***
*Cope's arboreal alligator lizard (Abronia aurita) is adapted for living high in the canopy of tropical rain forests; they hold on with their prehensile tails*

**Genera** 13
**Species** 101



S. Asia, S.W. Asia, Europe & Americas

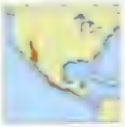
## CONSERVATION WATCH

The 10 species of Anguidae listed on the IUCN Red List are categorized as follows:

- 1 Extinct
- 3 Critically endangered
- 1 Endangered
- 1 Vulnerable
- 1 Near threatened
- 3 Data deficient

## FACT FILE

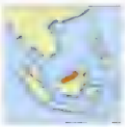
**Family Helodermatidae** The Gila monster and the Mexican beaded lizard are the only known venomous lizards. They have broad, flattened heads, and stocky bodies, strong limbs, and thick tails that are used for fat storage. Both species are nocturnal, sedentary, and diurnal. They feed on nestlings and hatchling birds' eggs.



Genera 1
Species 1

[illegible] to Guatemala

**Family Lanthanotidae** These earless monitors have unequal teeth and lack a palate and ear. They are related to the varanids and Helodermatidae. The species is nocturnal and semi-aquatic, living along and in forest streams. Monitors forage in the water and on land for small vertebrates and invertebrates. They are oviparous with clutches of up to six eggs.



Genera 1
Species

Borneo

## SHEDDING SKIN

The outer layer of a lizard's skin, the epidermis, is composed of keratin, scales, and thickenings. If this layer, as the lizard grows, the outer layer of keratin is shed in large flakes.

*Splitting out*

[illegible]

## CONSERVATION WATCH

**Added protection** Both species of Helodermatidae are listed on the IUCN Red List as vulnerable. The Gila monster is given complete protection in Arizona, United States. It is illegal to kill, wounding, trade, and hang and displaying the pet trade. Arizona has [illegible] species, so the Gila should be adopted and on the conservation [illegible] and cannot be killed, sold, and then sold as [illegible] made.

1 Mexican beaded lizard
*Heloderma horridum*
family Helodermatidae

2 Spiny-tailed monitor
*Varanus acanthurus*, family Varanidae

3 Roughneck monitor
*Lanthanotus borneensis*, family Lanthanotidae

4 Emerald monitor
*Varanus prasinus*, family Varanidae

5 Gila monster
*Heloderma suspectum*, family Helodermatidae

6 Borneo earless monitor
*Lanthanotus borneensis*
family Lanthanotidae

7 Pygmy Mulga monitor
*Lialeuff pygmaeus*, family Varanidae

Komodo dragons have an extremely virulent symbiotic bacteria living in their mouths; within a few hours of being bitten, wounded prey will lose energy due to a fever caused by the bacteria, then drop to the ground. The dragon trails the animal and eats it when it is down

1 Crocodile monitor
*Varanus salvadorii*, family Varanidae

2 Perentie
*Varanus giganteus*, family Varanidae

3 Gray's monitor
*Varanus olivaceus*, family Varanidae

4 Desert monitor
*Varanus griseus*, family Varanidae

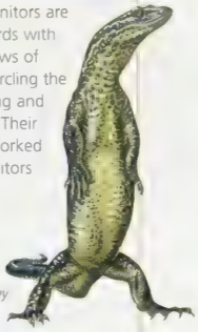
5 Sand monitor
*Varanus gouldii*, family Varanidae

6 Nile monitor
*Varanus niloticus*, family Varanidae

7 Komodo dragon
*Varanus komodoensis*, family Varanidae

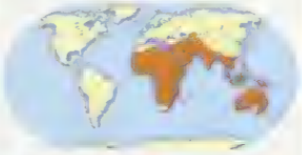
## FACT FILE

**Family Varanidae** Monitors are large, long-necked lizards with thick skin and many rows of small, rounded scales circling the body. Their tails are long and lack caudal autonomy. Their tongues are long and forked. The largest of the monitors is the komodo dragon



***Standing tall*** *The sand monitor has an extremely thick tail, allowing it a firm tripod stance when searching for mates or prey*

**Genera** 1
**Species** 50



Africa, Asia, Australia & Pacific Is

## JACOBSON'S ORGAN

A large number of lizards sense the air around them with their tongues, picking up chemical cues regarding food, conspecifics, likely mates, and predators. The Jacobson's organ has a pair of cavities lined with sensory cells on the roof of the mouth. The particles collected on the lizard's tongue are transported to ducts leading to these cavities by the tongue, explaining why the tongue is forked. The vomeronasal nerve then transmits the information collected to the brain for action

***Tongue testing*** *Monitors and many other lizards pick up airborne scent from their forked tongues*

## CONSERVATION WATCH

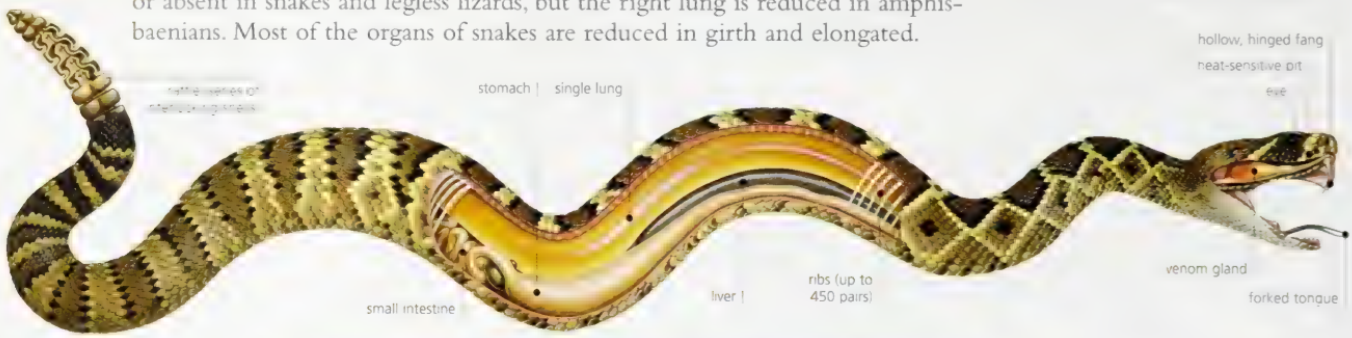
**Monitoring monitors** Many species of monitors are killed for their skins and meat. In Asia and Africa, they are exploited for traditional medicines; they also make up part of the diet of Australian indigenous people. More than a million Nile and other Asiatic monitors are killed annually for their skins, which are used in the manufacture of luxury shoes, belts, purses, and accessories

# SNAKES

CLASS Reptilia
ORDERS Squamata
FAMILIES 17
GENERA 438
SPECIES 2,955

At nearly 3,000 species, the variety in snakes is enormous. They range from the tiny burrowing blind snakes of a few inches (10 cm) long to huge constrictors over 33 feet (10 m) in length. Snakes have evolved special methods of locomotion, different ways of gathering environmental cues, and diverse venom delivery systems. Lizards appeared in the fossil record before snakes, and the presence of vestigial pelvic girdles and spurs in some primitive snakes indicates that snakes have evolved from them; the left lung is reduced or absent in snakes and legless lizards, but the right lung is reduced in amphisbaenians. Most of the organs of snakes are reduced in girth and elongated.

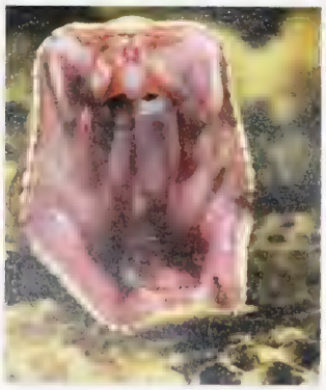
**Tropic lovers** Snakes are found on all continents except Antarctica, and ranges of some even pass above the Arctic circle. Some islands are also devoid of snakes, such as New Zealand, Ireland, and Iceland, and sea snakes are absent from the Atlantic. Snake biodiversity is highest in the tropics.




**Snake anatomy** As in the example of the Western diamondback rattlesnake (above), most snake organs have been reduced in diameter and have increased in length. Lungs in most species have been reduced to one, but males have two functional reproductive organs.

**Defensive display** Most species of cobras, such as the Cape cobra (*Naja nivea*) (right), have a hood that they can spread to look larger than life in order to frighten enemies or to transfix prey. The dorsal surface of the hood of some species [illegible] large eyelike spots to suggest the eyes of a much larger animal.

**Hidden fangs** When pit vipers, including timber rattlesnakes (below), threaten with [illegible] their fangs [illegible] the [illegible] These scan [illegible] prey.



## AN EAR TO THE GROUND

Snakes are very close to their environment. In fact, their bellies are in contact with the substrate most of the time—only when they are gliding between trees, swimming, or climbing trees are they free from this close contact with the ground. It is through this earthy contact that they pick up sound vibrations and follow the scent trails of prey and receptive females.

The shape of the snake determines where it will live and what it will do. Shovel-nosed snakes and worm snakes remain within the ground with modified snouts for burrowing and feeding on their subterranean prey. The slender, thin-necked, arboreal snakes are adapted for gliding through the branches and stretching out to reach the next branch only a nose away. They have small clutches of elongate eggs and eat thin, elongate prey, such as lizards or frogs. Short, thick-bodied snakes, like some vipers, are sit-and-wait predators and often gorge on a meal that weighs more than they do. Their awkward shape does not affect them, as they do not move much anyway, and many are venomous. Long-bodied, agile, fast-moving snakes are the athletes in the group, chasing down lizards and other snakes, and using their speed for escape. It is amazing how fast mambas and whip snakes can move

Granular scales

Smooth scales

Keeled scales

## SNAKE SKIN TYPES

Snake skin is made up of scales, which are not separate items, but a thickened part of the skin connected to other scales by thinner areas of elastic skin. Fine, granular scales are common in boas, the smooth, glossy overlapping scales are common in racers, and strongly keeled scales are characteristic of rattlesnakes.

*Poised to strike* This [illegible]

*Infrared sensors* [illegible]

**Green constrictors** The green tree python is an ambush predator. Feeding on birds, mammals, and lizards. Grasping a bird or perhaps the unguard its long teeth, in simultaneously throws a coil around the prey and constricts it. The hatchlings of the green tree python are 10–14 inches, 28–35 cm long and are colored differently from the adults. The vivid juvenile color pattern transforms to a vivid green in 6–8 months.

**Fang varieties** Rear grooved fangs are associated with Duvernoy's gland secretions in Colubridae. Elapidae (cobras, coral snakes, sea snakes, and taipans) have fixed short front fangs. The vipers all have hinged front fangs

**Keen vision** The long [illegible] round [illegible] not acute [illegible] vision. They are designed for detecting the slightest motion of their preferred prey—other snakes—within the [illegible]

through the forest canopy: they do not slither, but flow like a stream of water. Sea snakes have modified their shape to have a paddle-like tail, useful for a pelagic life. Many species never touch land, but feed, breed, and give birth at sea.

All male snakes have two hemipenes in the base of the tail; they are usually used alternately, each receiving sperm from only one of the testicles. This system perhaps evolved from the selective advantage of having a fast recovery time when participating in mass spring orgies following emergence from hibernation. Sperm can be stored for months or more than a year before it is utilized to fertilize eggs.

Females have evolved a range of modified behavior patterns to enhance their genes. Most snakes lay eggs, but many of the more recent snakes have evolved viviparity and some parental care. Through muscle contractions, pythons can raise their body temperatures when brooding their eggs. Female cobras guard their nest of eggs in a loose construction of leaves built over the nest.

Some of the most fantastic adaptations of modern snakes are the mechanisms they have developed for finding, capturing, killing, and swallowing prey. Highly developed chemical receptors on the roof of the mouth help snakes to identify mates, enemies, and prey. Infrared receptors possessed by pit vipers, boas, and pythons allow them to visualize warm-blooded prey in terms of heat. The venom produced by Viperidae, Elapidae, and Colubridae allow them to stop prey in its tracks and help in swallowing and digesting the meal. Obviously some snakes have evolved more than others, and many are now losing ground—humans are changing the environment faster than snakes can evolve.

**Hatchlings emerge** Most pythons guard and incubate their eggs. However, once their first week outside the shell is over, the young shed their skins, leave the protective coil of the mother, and disperse like the young green tree python below.

## FACT FILE

**Family Tropidophiidae** These West Indian dwarf boas are small, about [illegible] in weight. The island Tatar is thought to have diverged from a common mainland ancestor. They eat frogs, lizards, rodents, and birds. Other distinctive [illegible] these snakes breed from the mouth and eyes and roll up into a tight ball as a defensive mechanism.

Genera [illegible]
Species [illegible]

[illegible] Asia

## BOA AND PYTHON SKULLS

The [illegible] jaws of snakes are designed to swallow objects up to five times their diameter. Teeth are curved so that by first moving one side and then the other, the food is pushed down the throat.

resting jaw

*Full gape* [illegible]

## CONSERVATION WATCH

**Round Island boas** The now-extinct [illegible] boa (*Bolyeria multocarinata*) [illegible] found only on Round [illegible] in. Another [illegible] (*Casarea dussumieri*) [illegible] due to the [illegible] damage on this island. [illegible]

Male Mexican rosy boas have well-developed spurs, those of the female are smaller.

Tatar sand boas are sold for high prices in central Asia for medicinal purposes.

1 Mexican rosy boa
*Lichanura trivirgata*, family Boidae

2 Wood snake
*Tropidophis melanurus*, family Tropidophiidae

3 New Guinea ground boa
*Candoia aspera*, family Boidae

4 Calabar ground python
*[illegible] hardtii*, family Boidae

5 Rubber boa
*Charina bottae*, family Boidae

6 East African sand boa
*Gongylophis colubrinus*, family Boidae

7 Schaefer's dwarf boa
*Xenophidion schaeferi*, family Tropidophiidae

8 Isthmian dwarf boa
*Ungaliophis continentalis*, family Tropidophiidae

9 Tatar sand boa
*Eryx tataricus*, family Boidae

10 Feick's dwarf boa
*Tropidophis feicki*, family Tropidophiidae

Because of its gentle disposition and beautiful pattern, the Indian python has been prized in the pet trade for decades; now most individuals sold are captive-born

Heat-sensing pits are located in the labial scales

Tongue is used to collect airborne scents

1 Common boa constrictor
*Boa constrictor*, family Boidae

2 Indian python
*Python molarus*, family Boidae

3 Madagascar ground boa
*Acrantophis madagascariensis*, family Boidae

4 African rock python
*Python sebae*, family Boidae

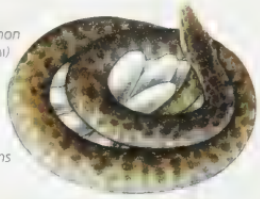
5 Reticulate python
*Python reticulatus*, family Boidae

6 Anaconda
*Eunectes murinus*, family Boidae

7 Emerald tree boa
*Corallus caninus*, family Boidae

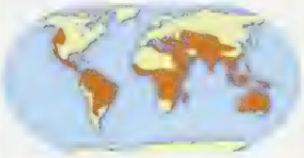
## FACT FILE

**Family Boidae** This family includes the boas, pythons, and sand boas—the largest living snakes—but some species are less than 20 inches (50 cm) long. The largest may reach 33 feet (10 m) and feed on large mammals, capybaras, deer, and caimans. Boas and sand boas are viviparous; pythons are oviparous.



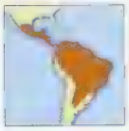
***Egg brooding***
*The children's python (Antaresia childreni) coils around its eggs to conceal and protect them. It increases body temperature by muscle contractions*

**Genera** 20
**Species** 74



Worldwide except Europe and Antarctica

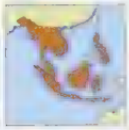
**Common boa constrictor** Boas are heavy-bodied arboreal snakes that kill their prey by constriction. They have vestigial legs as spurs on either side of the cloaca, which suggests that they are of ancient origin.



Up to 14 ft (4.2 m)
Terrestrial, arboreal
Viviparous
30–50
Common

S. Mexico to Argentina

**Reticulated python** One of the two largest snakes in the world, this python is more massive than the anaconda. Its prey includes large reptiles, such as lizards and crocodilians, and medium to large mammals, even humans.



Up to 33 ft (10 m)
Terrestrial
Oviparous
80–100
Common

S.E. Asia

## CONSERVATION WATCH

The 10 species of Boidae on the IUCN Red List are categorized as follows:

1 Extinct
2 Endangered
4 Vulnerable
3 Near threatened

## FACT FILE

**Green tree python**

*Polymorphic colors*

**Cook's tree boa**

**Black-headed python**

**Blood python**

Green tree python
*Morelia viridis*, family Boidae

Cook's tree boa
*Corallus cookii*, family Boidae

Carpet python
*Morelia spilota*, family Boidae

White-lipped python
*Leiopython albertisii*, family Boidae

Cuban boa
*Epicrates angulifer*, family Boidae

Black-headed python
*Aspidites melanocephalus*, family Boidae

Ball python
*Python regius*, family Boidae

Blood python
*Python curtus*, family Boidae

Mexican burrowing python
*Loxocemus bicolor*, family Loxocemidae

Coral cylinder snake
*Anilius scytale*, family Aniliidae

Sunbeam snake
*Xenopeltis unicolor*, family Xenopeltidae

Drummond hay's earth snake
*Rhinophis drummondhayi*, family Uropeltidae

Natal black snake
*Macrelaps microlepidotus*, family Atractaspidae

Mole viper
*Atractaspis engaddensis*, family Atractaspidae

Beaked burrowing asp
*Atractaspis bibronii*, family Atractaspidae

Red cylinder snake
*Cylindrophis ruffus*, family Cylindrophiidae

Arafura file snake
*Acrochordus arafurae*, family Acrochordidae

## FACT FILE

**Mexican burrowing python** [illegible]

S. Mexico to Costa Rica

**Family Atractaspidae** These [illegible] snakes are called stiletto snakes because they have a large hollow fang on each maxillary bone (upper jaw). They dig an underground [illegible] The tight spaces mean it is impossible for them to gape their mouths to strike, so they wiggle alongside their prey, [illegible] jaw to the opposite side from the prey, and expose their long fangs. They then proceed to envenomate their prey, stabbing it with a backslash motion.

Genera [illegible]
Species 18

**Family Aniliidae** These [illegible] colored coralsnake mimics [illegible] leaf litter and feed on earthworms, caecilians, eels, amphisbaenians, and snakes. They are occasionally found in the water, but are probably [illegible] dimensioned; they fall up into a pit.

Genera [illegible]
Species [illegible]

**Family Acrochordidae** These snakes have small, strongly keeled scales. The snakes are one of the most aquatic snakes, and are almost incapable of movement on land. They live [illegible] and feed on fishes with [illegible]

Genera [illegible]
Species [illegible]

Rosette tail

# SNAKE DEFENSE STRATEGIES

**Looping in alarm** The bandy-bandy (*Vermiculla annulata*) is a nocturnal, venomous elapid snake. It throws its body into loops off the ground when it is alarmed. It is possible that the snake is attempting to appear larger than it is by doing this, or that it is striking in a new direction to catch the predator off guard.

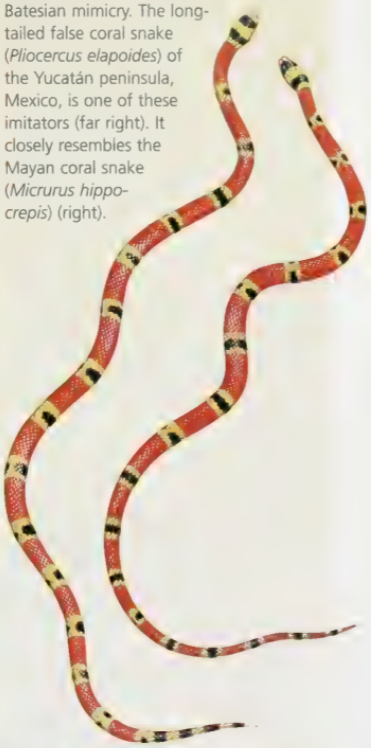
Snakes have many different strategies to avoid becoming a meal. Camouflage—utilizing color, pattern, and shape—is the most common tactic. Many arboreal snakes have long, slender heads and necks like twigs so that they blend in with their favored habitat. Escape works if you are very fast, like the red racer (*Masticophis flagellum*), which is built for speed. Many defensive maneuvers were designed to be effective against birds or mammals. The Indian cobra (*Naja naja*) raises half its body off the ground, spreads its hood, and displays large eye spots so that it appears to be a much larger animal. The Arizona coral snake (*Micruoides euryxanthus*) raises its tail and pops its cloaca to distract predators from attacking its head. The prairie ringneck snake (*Diadophis punctatus*) is black dorsally; when threatened, it hides its head in its coils and raises a coiled tail which is bright orange ventrally to startle its attacker. Many snakes will hiss, thrash, bite, and defecate to dissuade unwanted attention.

**Master of disguise** The eyelash viper (*Bothriechis schlegelii*), an arboreal pit viper, is perfectly camouflaged [illegible] in an appropriate perch on [illegible] for passing [illegible]. Its color and shape blend [illegible] that [illegible] are not alerted [illegible]

**Rattling good tail** When disturbed, a rattlesnake will vibrate its tail and make a loud rattling sound. The noise and the movement distract the potential prey or predators, who end up watching the tail and not the striking head. Many species of non-venomous snakes vibrate their tails as well.

**Surprise under the sand** Waiting for a meal to pass, the Peringuey's sidewinding adder (*Bitis peringueyi*) (below) becomes invisible as the shifting sand of the Namibian desert blows over it. The adder's pattern and coloration blend in with the golden sand; only its eyes and the black tip of its tail remain visible. Hiding is a good defense against canids and raptors.

**Mimicking danger** Many nonvenomous snakes have evolved color patterns similar to those of venomous species in their region, to reap the benefit this warning coloration has on predators. This adaptation is called Batesian mimicry. The long-tailed false coral snake (*Pliocercus elapoides*) of the Yucatán peninsula, Mexico, is one of these imitators (far right). It closely resembles the Mayan coral snake (*Micrurus hippocrepis*) (right).



**Feigning death** When molested, the Eastern hognose snake (above) hisses and strikes with a closed mouth. If this fails to deter a predator, the snake writhes and contorts its body; its mouth is open, and it discharges fetid cloacal fluids. After a few minutes it will roll onto its back and lie limply with its mouth open as though dead. The impact is lost if you turn the snake over, as it will immediately roll onto its back again.

***Aging rattles*** *The rattle grows one button each time the snake sheds its skin. This can be four to six times a year*

**Snake in the grass** When threatened, a bull snake (*Pituophis melanoleucus*) raises its head off the ground and expels air from its trachea; vibrating a cartilage at the tracheal opening creates a loud hissing sound. The tail is vibrated simultaneously, which produces a rattling sound in dry leaves or grasses. These effects combine to scare off most predators.

**Threat display** The venomous Florida cottonmouth (*Agkistrodon piscivorous*) opens its jaws to reveal a startlingly white mouth. This alerts predators to its presence and to the imminent danger. Sympatric nonvenomous water snakes have a similar color pattern and mimic this behavior for their defense

## FACT FILE

**Family Colubridae** About 63 percent of all species of snakes are included in this family, which utilizes all available reproductive styles and habitats. There are six loosely defined groups within the colubrids: Natricinae are small aquatic or terrestrial snakes; the largest group, Colubrinae, exploit all snake habitats except marine; the primarily oviparous Xenodontinae contains small, New World tropical and terrestrial species; Dipsadinae have diversified in Central and South America and occur in all available habitats; Homalopsinae contains 11 genera of diverse aquatic snakes occurring from northern Australia to Asia; and Aparallactinae are small snakes that range from sub-Saharan Africa to the Middle East

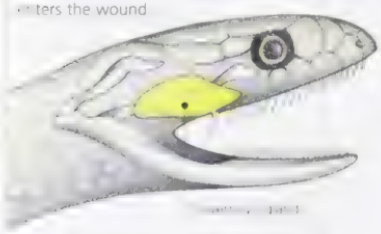
**Genera** 320
**Species** 1,800

Worldwide, except Antarctica & polar regions

***Snake trade***
*The brightly colored corn snake (Elaphe guttata) has been sought after in the pet trade for over 50 years because of its attractive colors and mild disposition. Captive breeding colonies are now providing most pet snakes sold today*

## COLUBRID VENOM

People often ignore the fact that most species of colubrids produce venom in the Duvernoy's gland. The venom is released and flows along grooved erect fangs in the back of the mouth. Since the venom is not forced through hollow fangs under pressure, as in front-fanged venom delivery (common to vipers and elapids), only about half enters the wound



***Non-lethal venom*** *When dispensed*

Indigo snake
*Drymarchon corais,*
family Colubridae

Spotted bush snake
*Philothamnus semivariegatus,*
family Colubridae

Gray-banded king snake
*Lampropeltis alterna,*
family Colubridae

Chinese slug snake
*Pareas chinensis,*
family Colubridae

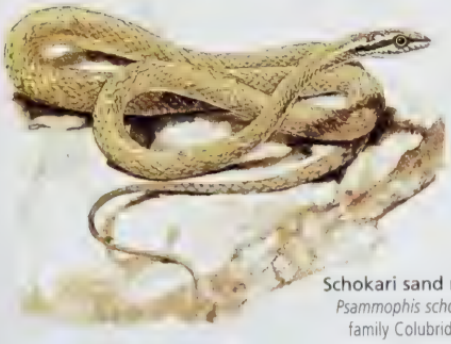
Milk snake
*Lampropeltis triangulum,*
family Colubridae

Aesculapian false coral snake
*Erythrolamprus aesculapii,*
family Colubridae

Milk snake
(juvenile color pattern)
*Lampropeltis triangulum,*
family Colubridae

Rhombic egg-eating snake
*Dasypeltis scabra,*
family Colubridae

Montpelier snake is rear-fanged and has venom potentially dangerous to humans

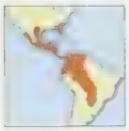


Schokari sand racer
*Psammophis schokar,*
family Colubridae

Montpelier snake
*Malpolon monspessulanus,*
family Colubridae

## FACT FILE

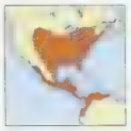
**Indigo snake** This large diurnal snake is highly prized by the pet trade for its dark, blue-black coloration and docile temperament. Indigos feed on turtle eggs, reptiles, amphibians, birds, small mammals, and snakes



Up to 8¾ ft (2.7 m)
Terrestrial
Oviparous
15–26
Uncommon

S.E. USA, Mexico to Paraguay

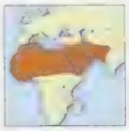
**Milk snake** This wide-ranging species is divided into 24 diverse subspecies Milk snakes often mimic the color pattern of coral snakes for defense



Up to 4 ft (1.2 m)
Terrestrial
Oviparous
8–12
Common

E. USA, Mexico to Venezuela & Ecuador

**Schokari sand racer** This slender, fast-moving, diurnal predator searches its desert habitat for prey. They have rear fangs and are mildly venomous.

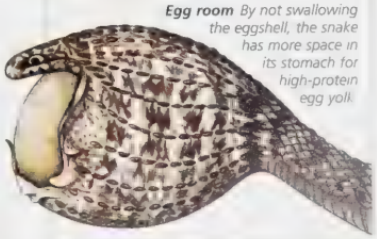


Up to 5¼ ft (1.6 m)
Terrestrial
Oviparous
8–16
Common

N.W. India, Afghanistan, Pakistan to N. Africa

## SPECIALIZED EGG-EATERS

African egg-eating snakes have evolved vertebrae with blunt spines that pierce the egg as it is forced down by muscle contraction. The contents are squeezed out and the eggshell regurgitated



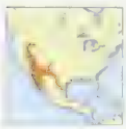
***Egg room*** *By not swallowing the eggshell, the snake has more space in its stomach for high-protein egg yolk.*

## CONSERVATION WATCH

**Hobby farming** In the 1970s in Texas, United States, the rare gray-banded king snake was protected, as it was popular with the pet trade. Hobbyists have since bred so many that wild populations have recovered and the species no longer needs protection.

## FACT FILE

**Western ground snake** This snake is secretive, inhabiting areas with loose alluvial sand in dry washes, creosote bushes, desert flats, and rocky hillsides. It prefers to hunt for prey at night and consumes centipedes, spiders, crickets, grasshoppers, and insect larvae.



Up to 20 in (50 cm)
Terrestrial
Oviparous
Unknown
Uncommon

S.W. USA & N.W. Mexico

**Common bronze-back snake** Bronze-backs are primarily arboreal in rain forest, coconut plantations, and urban areas. Frogs and lizards, including flying lizards (Draco), are consumed.

Up to 3¼ ft (1 m)
Terrestrial, arboreal
Oviparous
Unknown
Common

India, Burma, W. Malaysia, Indonesia, S. China

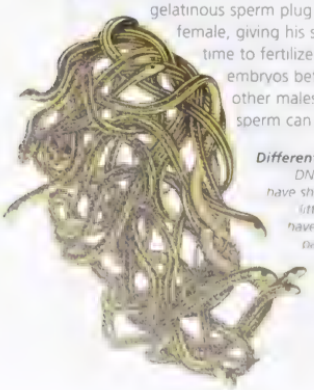
**Ring-neck snake** When attacked, these small woodland snakes hide their head and raise a coiled tail exposing the bright orange ventral surface. They feed on slugs, beetles, frogs, salamanders, and small snakes.

Up to 28 in (71 cm)
Terrestrial
Oviparous
1–7
Common

S.E. Canada, USA, N. Mexico

### GARTER SNAKE

In Canada, garter snakes (*Thamnophis sirtalis*) hibernate en masse in deep crevices below the frost line. In spring, thousands emerge simultaneously to bask and breed. Males trail receptive females by the scent trails they lay down; up to a hundred males can be in a ball courting the same female. After copulating, the male leaves a gelatinous sperm plug in the female, giving his sperm time to fertilize the embryos before other males' sperm can enter.



***Different fathers*** *DNA studies have shown that litters often have multiple paternities.*

1 Blue-necked keelback
*Macropisthodon rhodomelas*, family Colubridae

2 Red-necked keelback
*Rhabdophis subminiatus*, family Colubridae

3 European grass snake
*Natrix natrix*, family Colubridae

4 Northern water snake
*Nerodia sipedon*, family Colubridae

5 Queen snake
*Regina septemvittata*, family Colubridae

6 Masked water snake
*Homalopsis buccata*, family Colubridae

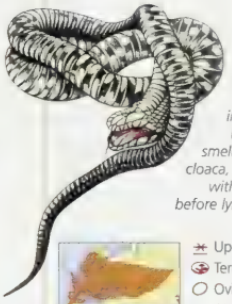
7 New Guinea bockadam
*Cerberus rynchops*, family Colubridae

8 Tentacle snake
*Erpeton tentaculatum*, family Colubridae

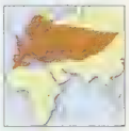
9 Rainbow water snake
*Enhydris enhydris*, family Colubridae

## FACT FILE

**European grass snake** This is one of the few reptiles to live inside the arctic circle and above 7,000 feet (2,121 m) Frogs are one of their main dietary items. Declining frog populations mean grass snake numbers are falling



***Dead or alive?*** *When grass snakes are attacked, they inflate with air, hiss, bite, release a foul-smelling liquid from the cloaca, and writhe around with their mouth open before lying limp as if dead*



Up to 6½ ft (2 m)
Terrestrial, aquatic
Oviparous
15–35
Common

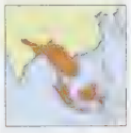
Europe, W. Asia, N.W. Africa

**Queen snake** The queen snake is endangered in parts of its range due to habitat destruction and pollution. This water snake inhabits cool, clear streams, where it forages for newly molted crayfish under flat rocks.

Up to 36½ in (93 cm)
Aquatic
Ovoviviparous
5–23 live young
Status

S.E. Canada, E. USA

**Masked water snake** This nocturnal aquatic snake feeds on fishes and frogs. It has well-developed Duvernoy's glands and grooved, posterior maxillary teeth. Duvernoy's secretions are used to incapacitate prey animals, which makes them easier to eat.



Up to 4 ft (1.2 m)
Aquatic
Viviparous
Unknown
Common

S.E. Asia

**Rainbow water snake** This tropical water snake feeds primarily on fresh-water fish and is not tolerant of salt water. It is the main aquatic snake in most wetland habitats in South-East Asia, but is at risk from the intrusion of salt water, associated with El Niño, into its habitats

Up to 32 in (81 cm
Aquat

S.E. Asia

## FACT FILE

**Mangrove snake** This rear-fanged snake has mildly potent venom, and is capable of killing humans. They are semiarboreal, feeding on small mammals, tree shrews, birds, and other snakes in mangrove swamps

Up to 8¼ ft (2.5 m)
Aquatic, arboreal
Oviparous
7–14
Common

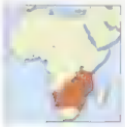
S.E. Asia

**Boomslang** This venomous snake is the most dangerous colubrid. It is a rear-fanged snake, but its venom is more potent than that of cobras or vipers and causes internal bleeding. Boomslangs are active snakes that feed mainly on chameleons and other tree lizards, nestling birds, and eggs

Up to 6 ft (1.8 m)
Arboreal
Oviparous
10–25
Common

Sub-Saharan Africa

**Cape twig snake** This is a venomous rear-fanged colubrid, capable of inflicting fatal bites on humans. The venom causes internal bleeding. The twig snake has special cartilage in the throat that allows it to puff its neck up greatly in a threat display



Up to 5¼ ft (1.6 m)
Arboreal
Oviparous
4–13
Common

Sub-Saharan Africa

## BROWN VINE SNAKE

These diurnal snakes forage in the lower branches of neotropical forests, where they easily strike and capture passing ground-dwelling lizards. They also feed on arboreal lizards, frogs, small birds, and small mammals

***Look, no hands***

Rear-fanged nocturnal predator of lizards and birds; mildly venomous

1 Mangrove snake
*Boiga dendrophila*, family Colubridae

2 Brown vine snake
*Oxybelis aeneus*, family Colubridae

3 Long-nosed tree snake
*Ahaetulla nasuta*, family Colubridae

4 Boomslang
*Dispholidus typus*, family Colubridae

5 Paradise flying snake
*Chrysopelea paradisi*, family Colubridae

6 Cape twig snake
*Thelotornis capensis*, family Colubridae

7 Mediterranean cat snake
*Telescopus fallax*, family Colubridae

8 Forest flame snake
*Oxyrhopus petola*, family Colubridae

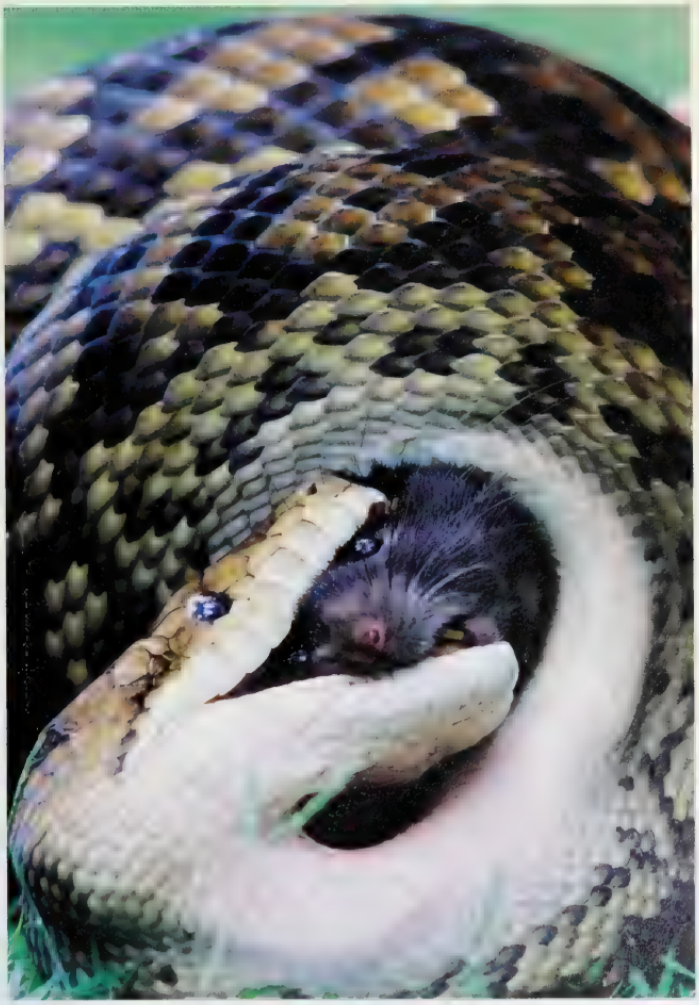
# SNAKES AS PREDATORS

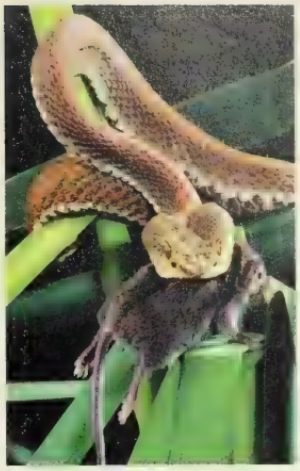
All snakes are carnivorous. The variety of prey sizes and taxa ranges from termites to crocodiles. Small snakes that feed on invertebrates search for their prey by sight or smell, often attacking them in their nests. Snakes use their tongues to collect scent data on where their prey has been and often trail them or wait for them to return; many of the large vipers and constricting snakes wait along rodent or game trails for prey to come to them. The large-eyed diurnal racers and whipsnakes are visual predators and chase down lizards and other snakes. The venom that vipers, elapids, and some colubrids inject to kill their prey also helps in the digestion of the animal, since venom is an enzyme. Many large snakes eat a meal only a few times a year, but sometimes this meal has a greater mass than they do.

***Heat vision*** *Carpet pythons (Morelia spilota), with their labial heat-sensing pits, are able to detect and identify the size of a warm-blooded object before seeing it optically.*

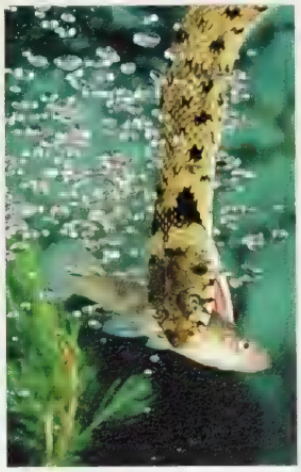
**Snake-eaters** Many species of snakes, including the king cobra (above), feed on other snakes such as coral snakes, king snakes, indigo snakes, and mussarnas. Snakes are easy to swallow and the protein is easily digestible.

**Egg-eaters** The egg-eater snake (*Dasypeltis scabra*) has a gland behind each eye that may supply extra fluids to the mouth to lubricate egg shells for swallowing. It can swallow an object about three times its diameter





**Strike force** The eyelash viper (*Bothriechis schlegelii*) (above) is an arboreal sit-and-wait predator, ready to rapidly identify prey through visual, infrared, and olfactory cues. It strikes on a moment's notice, as a bird, bat, lizard, frog, or in this case, rodent, passes by



**Gone fishing** The mild venom of the Duvernoy's gland is sufficient to paralyze a fish. The grass snake (*Natrix natrix*) (above) can then more easily manipulate it for swallowing. All snakes swallow their prey whole

**Suffocation** Many snakes, not just pythons, boas, and anacondas, constrict their prey to kill it. The amethyst python (*Morelia amethistina*) (left) captures prey in its teeth and simultaneously wraps itself around it. The coils get tighter as the animal exhales, and it dies from suffocation. The bones of the prey are broken in the process.

## FACT FILE

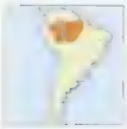
**Catesby's snail eater** These nocturnal snakes stalk snails and slugs. They extract the snail meat from the shell with their toothed mandible

Up to 28 in (71 cm)
Terrestrial, arboreal
Oviparous
1–5
Common

Amazonia (N. South America)

***Color change*** *When young, mussuranas have a bright warning coloration, which transforms into a black stealth color as it ages*

**Amazon false ferdelance** When alarmed, this snake will flatten its head and neck and distend its neck to make a hood. It is a rear-fanged snake, so the bite is potentially dangerous



Up to 4 ft (1.2 m)
Terrestrial
Oviparous
9–26
Common

Amazonia (N. South America)

**False water cobra** These snakes are not highly dangerous, but their bites have caused serious side-effects in humans, so they should be treated with care. Adults both bite and constrict mammals and birds, but swallow frogs and fishes directly

Up to 9 ft (2.8 m)
Aquatic
Oviparous
20–36
Common

N. South America

## CONSERVATION WATCH

The 37 species of Colubridae on the IUCN Red List are categorized as follows

1 Extinct
6 Critically endangered
7 Endangered
8 Vulnerable
9 Near threatened
10 Data deficient
11 Least common

Egyptian cobra
*Naja haje*, family Elapidae

King cobra
*Ophiophagus hannah*, family Elapidae

Ringed water cobra
*Boulengerina annulata*, family Elapidae

Monocled cobra
*Naja kaouthia*, family Elapidae

Venom can cause blindness if not treated

Spitting cobra
*Naja nigricollis*, family Elapidae

Western green mamba
*Debdroaspis viridis*, family Elapidae

Black mamba
*Dendroaspis polylepis*, family Elapidae

Fastest snake known: clocked at up to 12½ miles per hour (20 km/h)

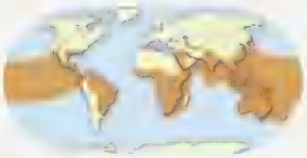
Blue Malaysian coral snake
*Maticora bivirgata*, family Elapidae

Banded krait
*Bungarus fasciatus*, family Elapidae

## FACT FILE

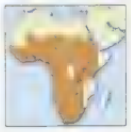
**Family Elapidae** This family comprises the cobras, kraits, seasnakes, coral snakes, death adders, and allies. Elapids are venomous, with anterior erect fangs on each maxilla. Only the mambas and tree cobras are arboreal. Many are burrowing or leaf-litter snakes and have bright coloration. Most terrestrial species are oviparous or viviparous. All true sea snakes are viviparous, giving birth in the water. The sea kraits lay eggs on land.

**Genera** 62
**Species** 300



Worldwide except Antarctica & Atlantic

**Spitting cobra** Although this species usually does not bite, it can squirt its venom accurately up to 9 feet (2.6 m), aiming for its attacker's eyes.



Up to 7¼ ft (2.2 m)
Terrestrial
Oviparous
10–22
Common

Sub-Saharan Africa

**Black mamba** This large snake carries enough neuro-toxic venom to kill up to 10 adult humans. It is one of the fastest and most fearless snakes known. It can strike out to 40 percent of its length (most snakes only manage 25 percent).

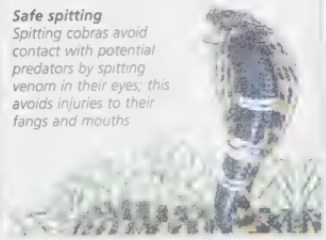
Up to 14 ft (4.2 m)
Terrestrial, arboreal
Oviparous
12–14
Common

Africa

## SPITTING COBRA

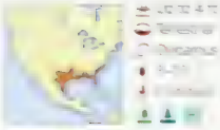
Spitting cobras have an opening on the anterior surface of the fang above the tip. For better accuracy, the inside of the fangs have spiral grooves that put a spin on the projected venom

***Safe spitting***
*Spitting cobras avoid contact with potential predators by spitting venom in their eyes; this avoids injuries to their fangs and mouths*



## FACT FILE

**Eastern coral snake** Even though it [illegible] the surrounding desert, this snake is [illegible] venomous to humans because [illegible] Despite its [illegible] the coral pattern.



**Redtail coral snake** [illegible] in January and March in March, hatchlings are the photo [illegible] only 8 cm. Colors [illegible] snake. Different [illegible] the coral pattern in Costa Rica.

**Common death adder** These [illegible] snakes, given the [illegible] and little, [illegible] at the base of [illegible] death adders have [illegible] and flow venom.

## SNAKE EYES

The [illegible] of a snake [illegible] be seen [illegible] small, degenerate eyes [illegible] burrowers. Vertical elliptical [illegible] are typical [illegible] Large round [illegible] are some [illegible] predator [illegible] their prey.

## CONSERVATION WATCH

**Sea snake status** Crocker's sea snake [illegible] is listed on the IUCN Red List as vulnerable [illegible] species of [illegible] and the [illegible] to be found [illegible] in their [illegible] a [illegible] of so limited [illegible] in the Solomon Islands.

Eastern coral snake
*Micrurus fulvius*, family Elapidae

Arizona coral snake
*Micrurus* [illegible], family Elapidae

Redtail coral snake
*Micrurus mosquitus*, family Elapidae

Many-banded coral snake
*Micrurus multifasciatus*, family Elapidae

Loveridge's garter snake
*Elapsoidea loveridge*
family Elapidae

[illegible] garter snake is nocturnal and [illegible] and feeds on [illegible] although venomous, there are few [illegible]

Cape coral snake
*Aspidelaps lubricus*, family Elapidae

Common death adder
*Acanthophis antarcticus*
family Elapidae

Curl snake
*Suta suta*
family Elapidae

Black-striped burrowing snake
*Simoselaps semifasciatus*
family Elapidae

Taipan
*Oxyuranus scutellatus*, family Elapidae

Black tiger snake
*Notechis ater*, family Elapidae

Mulga
*Pseudechis australis*, family Elapidae

Western brown snake
*Pseudonaja nuchalis*, family Elapidae

Blue-lipped sea krait
*Laticauda erscauda*, family Elapidae

Olive-brown sea snake
*Aipysurus laevis*, family Elapidae

Yellow-belly sea snake
*Pelamis platurus*, family Elapidae

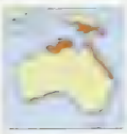
Turtle-headed sea snake
*Emydocephalus annulatus*
family Elapidae

Ornate reef snake
*Hydrophis ornatus*, family Elapidae

Scales on dorsal (back) side of snake (left, inset) are hexagonal in shape

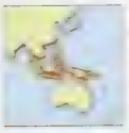
## FACT FILE

**Taipan** The taipan is the world's deadliest snake. Just 0.4 ml is enough of its venom to kill about one hundred humans, as well as 50 sheep and cows, seventy-five dogs, and over twenty-five thousand mice.



1 drop bites, instantly kills humans

**Blue-lipped sea krait** Unlike other sea snakes, sea krait are oviparous and lay their eggs on land. They do not have reduced venom ducts or a well-developed paddle-like tail. They often come to shore to digest large meals, another point of difference with other sea snakes, and possess muscles that are well developed for moving on land.

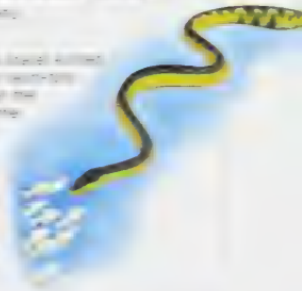


Under 0.1 km² (0.04 mi²)

## SEA SNAKES

Sea snakes were once grouped with hydrophiids, but are now part of the family Elapidae. They have many similar characteristics: all are venomous, and all exhibit the sea krait *Laticauda* are oviparous and give birth on land. All of these snakes have laterally compressed bodies, paddle-like tails, reduced ventral scales, and are incapable of moving well on land. There are 15 genera and 70 species distributed in Pacific, Indian Oceans, Australia, and tropical Pacific and Indian coasts.

**No table** Sea snakes number, with adults reaching length of 1 m, the most are little rarely, and their venom manifestations have not been sufficiently studied, many is little known.



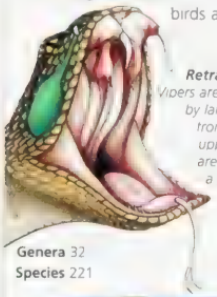
## CONSERVATION WATCH

They are species of Elapidae, one only Red List and endangered as follows:

1. vulnerable
2. least concerned

## FACT FILE

**Family Viperidae** All vipers are venomous, and possess movable front fangs. The pit vipers (rattlesnakes and [illegible]) have an external loreal pit for infrared detection. Adults range from 1 to 12½ feet (0.3 to 3.75 m) in length. The vipers lack the loreal pit; adults range from 1 to 6½ feet (0.3 to 2 m) in length. Most vipers have thick bodies and triangular-shaped heads. Young often eat amphibians, lizards, or snakes and change to a diet of mammals and birds as adults



***Retractable fangs*** *Vipers are characterized by large retractable front fangs in the upper jaw, which are used to inject a potent venom to prey and predators alike*

**Genera** 32
**Species** 221

Central & South America, Africa, Europe, Asia

## SIDEWINDER

The sidewinder (*Crotalus cerastes*) moves in loose sand by sidewinding. The head and neck are held off the sand and thrown sideways while the body remains in place. As soon as the head and neck hit the sand, the body and tail are hurled after it. As the tail touches the ground, the head and neck become airborne again, resulting in a continuous looping motion.

***Sidewinding***

Levantine viper
*Macrovipera lebetina*, family Viperidae

Rhinoceros viper
*Bitis nasicornis*, family Viperidae

Mauritanic viper
*Macrovipera mauritanica*, family Viperidae

Tropical rattlesnake
*Crotalus durissus*, family Viperidae

Gaboon adder
*Bitis gabonica*, family Viperidae

Pygmy rattlesnake
*Sistrurus miliarius*, family Viperidae

Copperhead
*Agkistrodon contortix*, family Viperidae

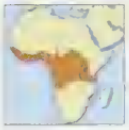
Banded rock rattlesnake
*Crotalus lepidus*, family Viperidae

Cantil
*Agkistrodon bilineatus*, family Viperidae

Western diamondback rattlesnake
*Crotalus atrox*
family Viperidae

## FACT FILE

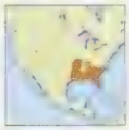
**Rhinoceros viper** This heavy-bodied viper has two to three horns on the tip of its snout and is venomous but not aggressive. It is a sit-and-wait predator and mostly preys on mammals



Up to 4 ft (1.2 m)
Terrestrial
Viviparous
6–35 live young
Common

C. & W. Africa

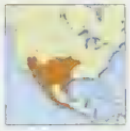
**Pygmy rattlesnake** The genus *Sistrurus* is distinguished by having nine large scales on the dorsal surface of the head. Young pygmy rattlesnakes have a bright yellow tail tip, which they wiggle as a lure to attract small prey



Up to 31½ in (80 cm)
Terrestrial
Viviparous
6–10 live young
Common

S.E. USA

**Western diamondback rattlesnake** One of the most abundant rattlesnakes in the United States, it is responsible for more snake bites there than any other snake. Diet is primarily rodents, but the young prey on lizards.



Up to 7½ ft (2.3 m)
Terrestrial
Viviparous
4–25 live young
Common

S.W. USA & N.W. Mexico

## RATTLE

Rattlesnakes have a unique rattle at the end of their tails. It is made up of interlocking segments of keratin; each time the snake sheds its skin, a new segment is added. When the tail is vibrating, the hollow segments bang against each other, making the anti-predator rattling sound

## CONSERVATION WATCH

The 20 species of Viperidae on the IUCN Red List are categorized as follows:

- 7 Critically endangered
- 4 Endangered
- 7 Vulnerable
- 1 Data deficient
- 1 Least concern

## FACT FILE

**Tiger rattlesnake** [illegible]

[illegible]

**Massasauga** Massasauga means great river mouth in the Chippewa language. The [illegible] refer to the sometimes swampy habitat in the floodplains of large rivers. They hibernate in crayfish burrows, after foraging for insects and frogs during the summer. When [illegible] their small, [illegible] sounds like the click of a cricket.

[illegible]

**Black-tailed rattlesnake** In the spring, males follow the chemical trails of females to court them. Courting and mating often last several days. Females give birth in August and stay with their young until they have shed for the first time. They find prey by following animal paths to burrows or nests and waiting for their chosen prey to return.

[illegible]

**Timber rattlesnake** These rattlesnakes [illegible] in rocky [illegible] habitats, usually on the south side of hills or mountains. Breeding usually takes place in the spring on the dam, [illegible] the nearest dispersal. The young [illegible] the dam [illegible] of the adults of [illegible] the fall. Although the species is primarily terrestrial, [illegible] have been found in the lower [illegible] of trees and [illegible] [illegible] in the [illegible] [illegible]

[illegible]

Tiger rattlesnake
*Crotalus tigris*, family Viperidae

Massasauga
*Sistrurus catenatus*, family Viperidae

Named for its solid black unbanded tail

Black-tailed rattlesnake
*Crotalus molossus*, family Viperidae

Twin-spotted rattlesnake
*Crotalus pricei*, family Viperidae

Ridge-nosed rattlesnake
*Crotalus willardi*, family Viperidae

Mojave rattlesnake
*Crotalus scutulatus*, family Viperidae

Speckled rattlesnake
*Crotalus mitchelli*, family Viperidae

Prairie rattlesnake
*Crotalus viridis*, family Viperidae

Timber rattlesnake
*Crotalus horridus*, family Viperidae

Wagler's palm viper
*Tropidolaemus waglen*, family Viperidae

White-lipped tree viper
*Trimeresurus albolabris*, family Viperidae

Yellow-blotched palm pit viper
*Bothriechis aurifer*, family Viperidae

Speckled forest pit viper
*Bothriopsis taeniata*, family Viperidae

Malayan pit viper
*Calloselasma rhodostoma*, family Viperidae

Hump-nosed moccasin
*Hypnale hypnale*, family Viperidae

Brazil's lancehead
*Bothrops brazili*, family Viperidae

Bushmaster
*Lachesis muta*, family Viperidae

Jararacussu
*Bothrops jararacussu*, family Viperidae

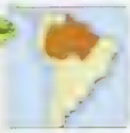
Hognosed pit viper
*Porthidium nasutum*, family Viperidae

## FACT FILE

**Wagler's palm viper** This viper can be identified by its normal color variety. It has long fangs and is brown, a mixture of black, yellow, red and hues (brownish).

[illegible]

**Bushmaster** This is the largest venomous snake in the Americas and the largest viper in the world. The ultimate sit-and-wait predators, traveling short distances between sites then waiting for days or weeks for a meal. The eggs are often laid in mammal burrows.



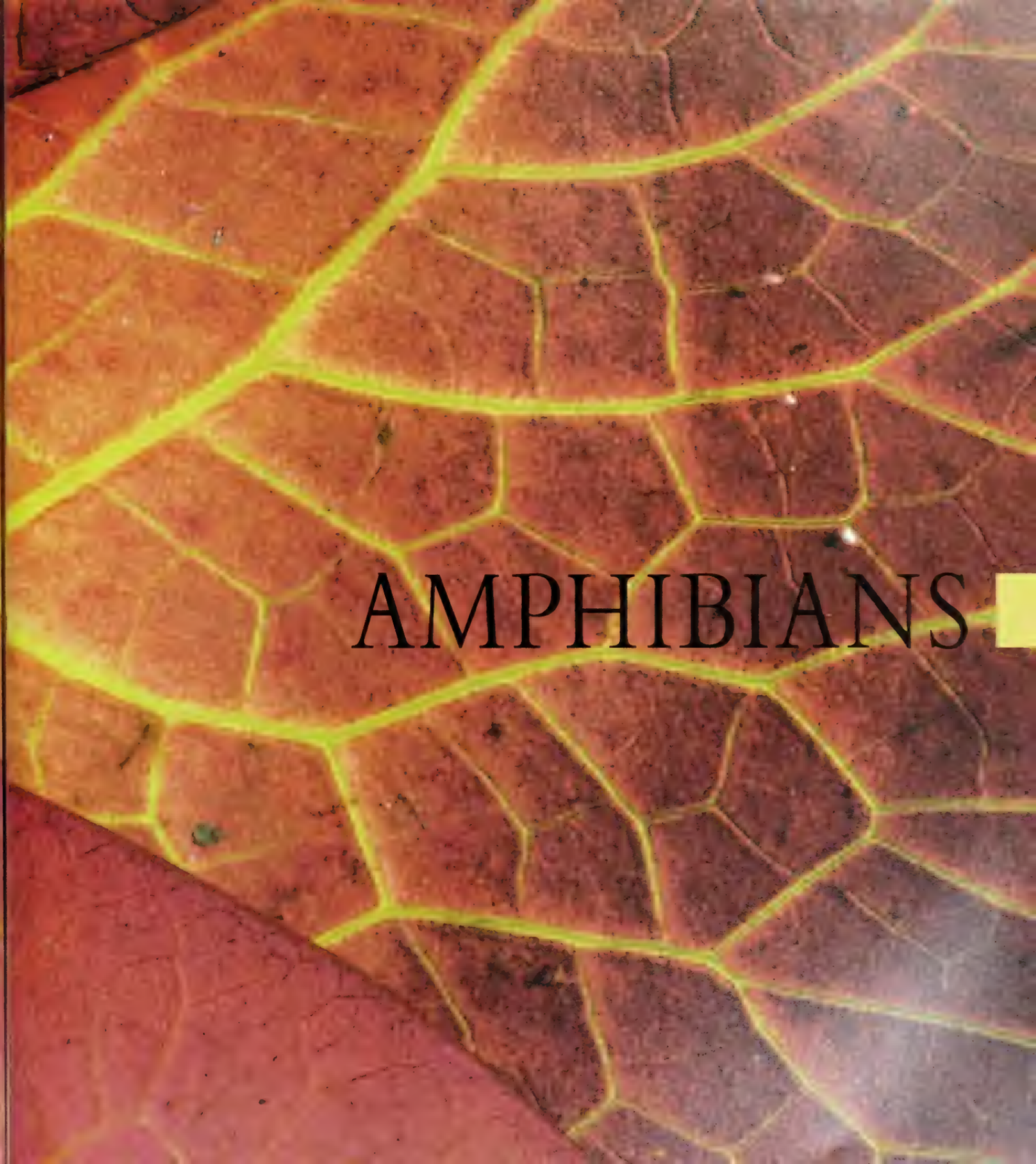
[illegible]

**Hognosed pit viper** These stocky snakes are called "jumping vipers" as their whole body appears to jump forward when they strike. In reality, they can only strike about half their length. This viper often swallows food whole, weighing more than its own.

Central America to Colombia & Ecuador

## PIT VIPER

Pit vipers have an infrared sensing pit organ that they use along with nostrils to help them evaluate a visual image. They can sense a mouse than 6 cms away, 100°C warmer than its surroundings when it is within 0.3 seconds.



# AMPHIBIANS

# AMPHIBIANS

| | |
|---|---|
| PHYLUM | Chordata |
| CLASS | Amphibia |
| ORDERS | 3 |
| FAMILIES | 44 |
| GENERA | 434 |
| SPECIES | 5,400 |

Amphibians appeared 360 million years ago. Descended directly from early lobe-finned fishes, they were the first vertebrates to become established on land, where they gave rise to the reptiles. Amphibians are cold-blooded, with moist skin and no scales or claws. There are three orders. Caecilians resemble earthworms, being limbless with bullet-shaped heads and tails. Salamanders (Caudata, meaning "with tail") have cylindrical bodies, long tails, distinct heads and necks, and well-developed limbs. Frogs and toads (Anura, meaning "lacking tail") differ from all other vertebrates in having stout, tailless bodies with a continuous head and body and well-developed limbs.

**Caecileans** The naked caecilian (*Siphonops annulatus*) is a typical fossorial form that has a burrowing life, with reduced eyes, a segmented body, and a fortified bullet-shaped head and tail. Although there are aquatic species as well, all are tropical, secretive, and rarely seen.

**Amphibian skin** The skin is moistened by mucus gland secretions. It maintains water balance, lubricates, and protects the body, filling level by bacterial antibiotics, or poisonous substances, including poisons in their predecessors. These developments are adaptations, their allowing being [illegible] and other beetles.

**Leaping for their lives** The red-eyed tree frog spends most of its life in the canopy of neotropical rain forests, in trees, vines, bushes, and even [illegible] its eggs in [illegible] tadpoles. These frogs are [illegible] a predator [illegible] in [illegible] tree frogs, [illegible] and [illegible] adulthood and [illegible] tree species [illegible]

## A DOUBLE LIFE

The word amphibian is from the Greek *amphibios*, meaning "a being with a double life." This refers to the reproductive cycle of most amphibians, in which they have an aquatic larval form and a terrestrial adult life. Most species breed and lay eggs in the water. In these cases, the young have a free-swimming larval stage with external gills, and metamorphose later into a miniature replica of the terrestrial adult. There are many exceptions to this. Some species have direct development on land and no larval stage. Others are entirely aquatic and viviparous. Still others are neotenic.

Some of the distinctive features that amphibians have developed to allow them to invade terrestrial habitats are: the tongue, which allows them to moisten and move food; eyelids, which along with adjacent glands wet and protect the cornea; an outer layer of dead skin cells that is regularly sloughed; ears; a sound-producing structure called the larynx; and the Jacobson's chemosensory organ in the nasal cavity, which gives them a sense of smell and taste.

An amphibian's skin is active in controlling water balance. This can be illustrated by looking more closely at frogs. The permeability of the skin is dynamic, changing with the activity cycle of the frog; when the frog is foraging away from water, the skin is highly permeable to absorb water. When the animal is aquatic, the permeability of the skin is reduced. Some terrestrial frogs have a special patch of skin in the pelvic region that is highly vascularized, allowing them to absorb water from any moist area. When frogs enter hibernation in the water, they must change their ionic balance and skin permeability to lower the absorption of water by osmosis. Some desert toads are able to absorb water from dry soils by retaining urea in their urine, thus creating an osmotic gradient across their skin.

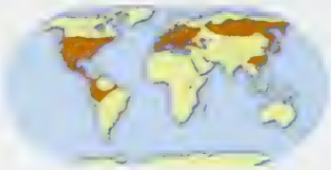
Adults of all amphibians are carnivores, although a few species of frogs have been reported to eat some fruits. The larvae of salamanders are carnivorous, while those of most anurans are herbivores. The tadpoles of some species of frogs are cannibalistic, as are the adults of many species.

**Male display** This male great crested newt (*Triturus cristatus*) (right) is in breeding condition. The males' dorsal and tail crests increase in size during the breeding season. After courtship in the water, the eggs are fertilized internally and deposited singly on vegetation. The larvae are carnivorous

# SALAMANDERS AND NEWTS

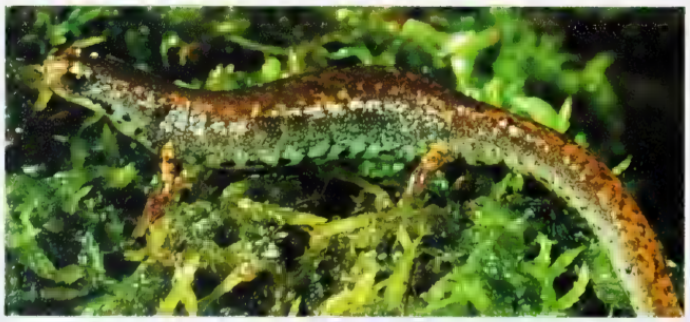
CLASS Amphibia
ORDER Caudata
FAMILIES 10
GENERA 60
SPECIES 472

Salamanders, newts, mudpuppies, waterdogs, and sirens belong to the order Caudata. All have tails and most have four legs. Most species are very secretive, living terrestrially in leaf litter or rotting logs, underground, in arboreal bromeliads, or underwater. Some live terrestrially but return to the water to reproduce. Although seldom seen, they are not uncommon; astoundingly, in some deciduous forests in North America, the biomass of salamander populations is greater than that of the birds and mammals. All salamanders and their larvae are carnivorous, and they in turn become prey for many larger carnivores, such as snakes, birds, and mammals.

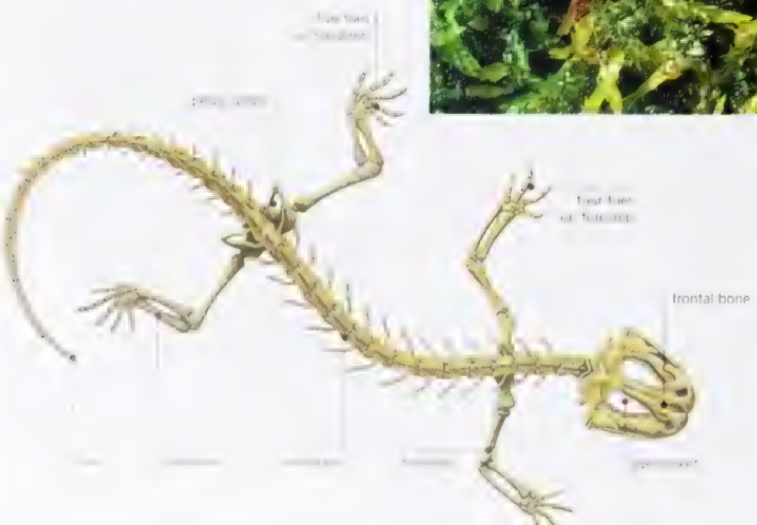


**Distribution** Salamanders are widely distributed in North and Central America, northern South America, Europe, northern Africa, and Asia

**Warning colors** The red salamander (*Pleurodeles ruber*) is semiaquatic, living in or under moss or flat rocks in or near springs or spring creeks. It prefers cool, clear water that flows through woods or meadows. Many species of salamanders are brightly colored to warn their principal predators—birds—that they are distasteful



**Four-toed salamander** *Hemidactylium scutam* lays up to 24 eggs under logs or in moss near clear-water creeks. The female guards them until they hatch; then the larvae enter the water to finish development




**Salamander skeleton** A salamander's vertebral column is rigid to support the head, pelvic and pectoral girdles, and viscera, but is also flexible, permitting lateral and dorsoventral movements. Salamanders have 10–60 presacral vertebrae and a variable number of postsacral vertebrae: 2–4 precaudals and a number of caudal vertebrae

## SILENT CARNIVORES

Salamanders evolved to live on land, with four legs and a tail. Some species have secondarily returned to live permanently in the water and have reduced limbs; these are known as sirens.

Salamanders more closely resemble early fossil amphibians than do frogs and toads. Unlike frogs, they do not emphasize vocal communications during breeding. The skin of salamanders is generally smooth, moist, and flexible, with oxygen exchange taking place through the skin. Many species have lungs as well, but some families lack lungs and respire entirely cutaneously. As the salamander grows, the skin is regularly shed. Because it is made up of the salamander's own cells and is easy to digest, the animal usually devours its own skin as it is sloughed.

Salamanders and their larvae are completely carnivorous. Adults consume insects, spiders, snails, slugs, worms, and other invertebrates. The larvae devour mosquito larvae and other insects. As they grow, they eat larger prey, including tadpoles and the larvae of the dragonfly that was once their feared predator. Some species of salamanders are able to extend their tongues rapidly for half the length of their body to capture prey.

Salamanders have moist, slippery skin, while newts, both in their aquatic and terrestrial phases, have rough, dry skin. Some species of newts live on land as adults, coming to the water only to breed, while the adults of some species are aquatic. Red-spotted newts are equally at home in the water or on land. The aquatic larvae metamorphose into a terrestrial red eft, and after 1–2 years on land return to the water to breed.

Hellbender
*Cryptobranchus alleganiensis*

Greater siren
*Siren lacertina*

Chinese giant salamander
*Andrias davidianus*

Lesser siren
*Siren intermedia*

Lacks eyelids

Two-toed amphiuma
*Amphiuma means*

Dwarf siren
*Pseudobranchus striatus*

Feathery protrusions near head are external gills

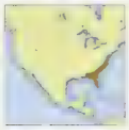
## FACT FILE

**Hellbender** Hellbenders live under rocks and thrive in streams, where they forage for crayfish, mollusks, and small fishes. They are harmless but extremely slimy; in order to pick them up, they must be grasped firmly around the head.

Up to 29½ in (74 cm)
Aquatic
Fall
Common

E.C. USA

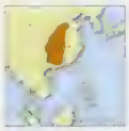
**Greater siren** Although most salamanders are silent, greater sirens when first caught will sometimes yelp. They also make clicking sounds, which perhaps may be used in intraspecific communication.



Up to 38½ in (98 cm)
Aquatic
Unknown
Common

S.E. USA

**Chinese giant salamander** Breeding takes place in an underwater cavity where the female lays up to 500 eggs in a cylindrical string. The male fertilizes the eggs externally and guards them until they hatch, in 50–60 days.



Up to 6 ft (1.8 m)
Aquatic
Fall
Data deficient

E.C. China

## SALAMANDER REPRODUCTION

During courtship, males of species that fertilize their eggs internally deposit sperm packets, or spermatophores, which are picked up by the cloacal lips of the females. Species with direct development lay eggs in moist areas, and the females guard the eggs until a miniature version of the adult emerges. Eggs laid in ponds or streams and attached to vegetation hatch within 1–2 weeks into free-swimming carnivorous larvae. Some species do not develop past their final larval stage.

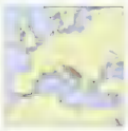
***Courtship consequences***
After courtship, the male

## FACT FILE

**Mudpuppy** These neotenic salamanders are [illegible] by their yellow, red, [illegible] gills (they have no lungs), [illegible] and large, flattened heads. Females laid [illegible] eggs, which they guard and aerate. Their eggs [illegible]

Up to 19 in (48 cm)
Aquatic
Rail
Vulnerable

**Olm** Olms live in flooded underground caves through Dinaric Alps, [illegible] adult olms [illegible] beneath the [illegible] cave. They are [illegible]. They lay up to 70 eggs, or they retain eggs and produce female fully [illegible].



Up to 12 in (30 cm)
Aquatic
Spring
Vulnerable

**Chinese salamander** This terrestrial salamander [illegible] moderate [illegible] breeding [illegible] are attracted to [illegible] or chemical [illegible] trail.

[illegible]

## CONSERVATION WATCH

**Going, going...** Three species of salamander are listed on the IUCN Red List as critically endangered. The Lake Lerma salamander (*Ambystoma lermaense*) has not been seen for years and is now presumed to be extinct. It was endemic to Lake Lerma, Mexico, which was affected by dam construction and pollution.

The Sardinian brook salamander (*Euproctus platycephalus*) is the most threatened salamander in Europe, due to pesticide (DDT) treatment of water bodies in the battle against malaria; the introduction of trout, which feed on and compete with the salamanders for food; and the reduction of water [illegible] due to [illegible].

The Desert slender salamander (*Batrachoseps major aridus*) [illegible] in Riverside County, California, United States. Active [illegible] lowers, this [illegible] is [illegible].

Luschan's salamander
*Mertensiella luschan*

European fire salamander
*Salamandra salamandra*

Olympic torrent salamander
*Rhyacotriton olympicus*

Golden striped salamander
*Chioglossa lusitanica*

Pyrenees mountain salamander
*Euproctus asper*

Californian giant salamander
*Dicamptodon ensatus*

Red-spotted newt
*Notophthalmus viridescens*

Common newt
*Lissotriton vulgaris*

Male in breeding condition

Luristan newt
*Neurergus kaiseri*

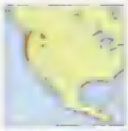
Banded newt
*Triturus vittatus*

## FACT FILE

**European fire salamander** [illegible]

Europe & N. Africa

**Californian giant salamander**
Females guard their 30 or more eggs for up to 6 months in crevices beneath rocks. Terrestrial adults often climb into low vegetation up to 8 feet (2.4 m) above the ground. The males make a loud rattling sound when disturbed.



N.W. USA

**Common newt** Males are smaller than females. During the breeding season, males develop a wavy crest, front head to tail, as well as a fringe on the hind toes. They remain in the breeding ponds from March to July, after which they are terrestrial.

Europe & W. Asia

## NEOTENY

Neoteny is the developmental state where the aquatic larval form with gills is maintained throughout adulthood. This usually occurs in species which live in oxygen-deficient water. Some species are permanently neotenic. The Mexican axolotl is neotenic, it [illegible] in the environment.

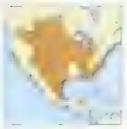
Fire salamander [illegible]

## FACT FILE

**Ringed salamander** This species has narrow crossbands, a slate-colored belly, and a light gray stripe along the sides of its thin body, unlike the marbled and tiger salamanders

Up to 9 in (23 cm)
Aquatic, burrowing
Fall
Common

**Tiger salamander** These salamanders are fossorial for most of the year, only emerging to breed once the early spring rains begin. After breeding in ponds or marshes, the adults retreat underground



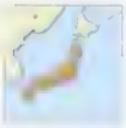
Up to 13 in (33 cm)
Aquatic, burrowing
Early spring
Common

S. Canada to Mexico

**Marbled salamander** This species congregates to lay up to 230 eggs in dry depressions from September to December. Females remain wrapped around the eggs, protecting them from predation and desiccation, until fall rains fill the pools

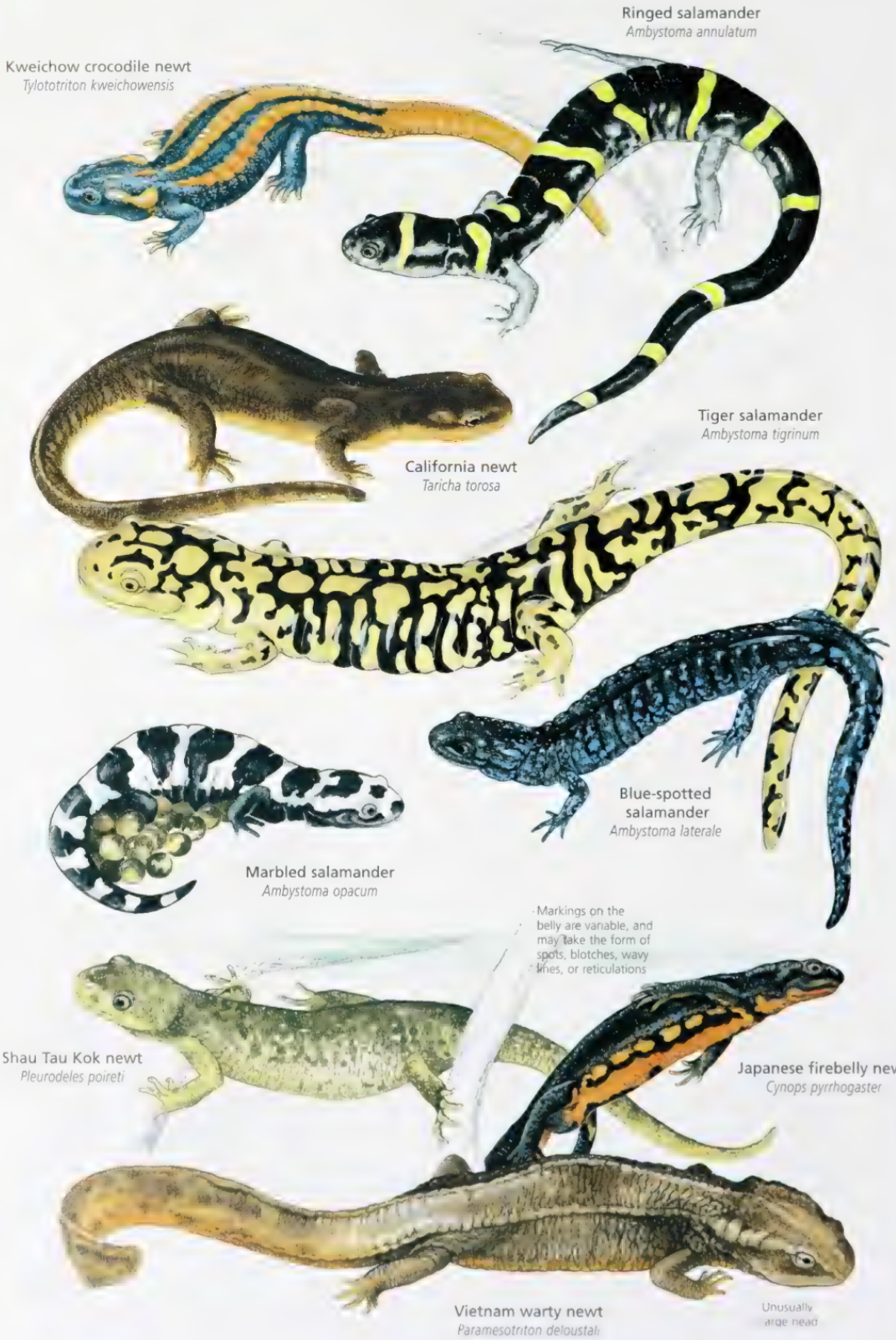
Up to 5 in (13 cm)
Terrestrial, aquatic
Fall
Common

**Japanese firebelly newt** Males of this species differ from females by having swollen cloacas. The tails of breeding males develop a bluish iridescent sheen and a small filament at the tip.



Up to 5¼ in (13.2 cm)
Aquatic

**Vietnam warty newt** This, the largest [illegible] the genus, is characterized [illegible] belly pattern of orange [illegible] spots, each with [illegible] mottling



Apennines salamander
*Speleomantes italicus*

Jackson's mushroomtongue salamander
*Bolitoglossa jacksoni*

Cave salamander
*Eurycea lucifuga*

Arboreal salamander
*Aneides lugubris*

Ensatina
*Ensatina eschscholtzii*

Spring salamander
*Gyrinophilus porphyriticus*

Northern dusky salamander
*Desmognathus fuscus*

Tennessee cave salamander
*Gyrinophilus palleucus*

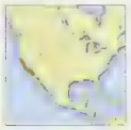
Red back salamander
*Plethodon cinereus*

Four-toed salamander
*Hemidactyliium scutatum*

Slimy salamander
*Plethodon glutenosus*

## FACT FILE

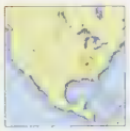
**Arboreal salamander** This aggressive species has a heavily ossified skull, strong jaws, hypertrophied jaw muscles, and enlarged, flattened, blade-like, monocuspid teeth. Scarred individuals are often found, presumably having survived conspecific attacks



Up to 4 in (10 cm)
Terrestrial, arboreal
Spring
Common, declining

Coast Ranges of California (USA)

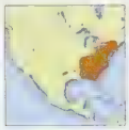
**Tennessee cave salamander** This species is primarily neotenic, although some individuals transform into the adult form, losing their gills. This salamander has vestigial eyes and reduced skin pigment



Up to 9 in (23 cm)
Aquatic
Spring
Common

Central Tennessee, N. Alabama (USA)

**Slimy salamander** Recently, each of the 13 genetic populations has been shown to be a distinct species. All are black with glue-like skin gland secretions.



Up to 8 in (20 cm)
Terrestrial
Spring
Common

S.E. USA

## LUNGLESS SALAMANDERS

Plethodontidae is the most diverse family of salamanders, with 269 species. Jordan's salamander (*Plethodon jordani*) inhabits the leaf litter and rotting logs on the humid forest floor of the Appalachian Mountains, in the eastern United States. It is adapted to cool, moist habitats up to 6,643 feet (1,993 m). Highly vascularized blood vessels near the skin's surface mean it can respire through the skin and lining of the mouth

***Desirable colors***
*The Jordan's salamander ha[illegible] a variety of colo[illegible] There are other species that mimic the col[illegible] this red-cheek[illegible] presumably be[illegible] a bad taste to predato[illegible]*

# AMPHIBIAN LIFE-CYCLES

Most amphibians have a dual life-cycle involving a courtship ritual, the deposition of sperm and eggs, external fertilization, an aquatic larval stage, and transformation into the adult life form. Modifications made to this cycle involve internal fertilization, direct development, viviparity, neoteny, or parental care. There is a trade-off between multitudes of small eggs with no parental care and a few large eggs with parental care.

**Swollen egg sacs** The egg sac of the Jefferson salamander (*Ambystoma jeffersonianum*) is much larger than the adult after the eggs have absorbed water. This species does not brood or guard its eggs.

**Salamander life-cycle** Pheromones stimulate courtship behavior in salamanders. Males then deposit sperm as spermatophores on the substrate below the female. She retrieves the spermatophores with her cloacal lips, fertilizing the eggs internally as she deposits them in water or in a moist substrate. Aquatic larvae hatch from the eggs in the water or direct development may occur in terrestrial eggs.

***1. Mating*** *The male clasps the female around the middle. The female carries the male until she is ready to lay her eggs. The male then sheds his sperm over the eggs as they are laid.*

***2. Egg development*** *The eggs float in large masses while the embryos develop inside. The eggs are covered in a jelly-like substance that swells when it comes into contact with water*

***5. Change complete*** *After 6 weeks, the metamorphosis from tadpole to adult frog is complete, and the young frog begins to hunt insects*

**Safe development** Marsupial frogs (*Gastrotheca*) have one or two pouches, similiar to those of marsupials, which open dorsally to the cloaca. Eggs are placed in the pouch as the male fertilizes them. Thus the eggs develop in a moist and safe environment. The young emerge as tadpoles or froglets, depending on the species

***4. Tadpole development*** *Lungs* [illegible] *tail*

***3. Tadpoles emerge*** *After 2 weeks, the eggs hatch into tadpoles. When the mouth develops, the tadpoles feed on algae. They breathe through external gills.*

**Frog life-cycle** Frogs and toads have a complex life-cycle. Males call to attact females, and shed sperm over the eggs as the female deposits them in a selected site. The eggs absorb water and in a few days develop into free-swimming tadpoles, which are normally herbivorous. After a few weeks, months, or years (depending on the species) the tadpoles metamorphose into identical small replicas of the adults. It then takes months or years of a carnivorous diet before sexual maturity is reached

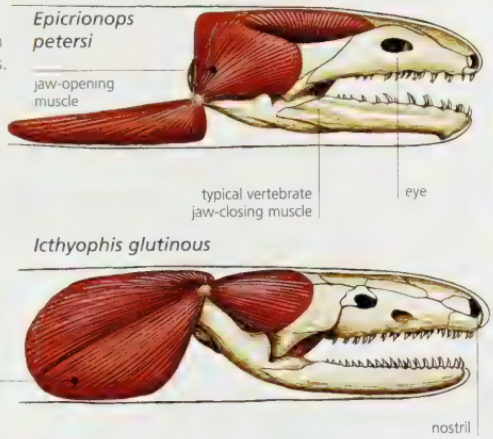
# CAECILIANS

| | |
|---|---|
| CLASS | Amphibia |
| ORDER | Gymnophiona |
| FAMILIES | 6 |
| GENERA | 33 |
| SPECIES | 149 |

Caecilians have radiated to a variety of aquatic and terrestrial habitats, with specialized characteristics for a fossorial life not present in any other vertebrates—chemo-sensing tentacles, an extra set of jaw-closing muscles, and skin that is ossified to the skull. Adults range in size from just under 3 inches (7 cm) to 5¼ feet (1.6 m). Fertilization is internal. Some species are oviparous; others have direct development; and about half of the known species are viviparous. They feed on earthworms, beetle larvae, termites, and crickets.

**Distribution** Caecilians have a limited pantropical distribution in india, southern China, Malaysia, the Philippines, Africa, Central America, and South America No species are known from Europe, Australia, or Antarctica

**Caecilian skull** Caecilians are built for burrowing, with massive, bullet-shaped skulls. They are streamlined, but reinforced for burrowing through soil or protruding into the substrate in search of invertebrate prey. They move through the soil by undulating the body: the muscles move in a wave from the head to the tail. The body curves resist the soil or water, and forward motion is achieved.



**Gymnophis multiplicate** All species in the family Caeciliidae are chacterized by distinct annuli, which have caused some people to confuse them with earthworms. Caecilians have a retractable tentacle on each side of the head, which helps them to search for prey by transmitting chemical clues to the nasal cavity.

### YOUNG CAECILIANS

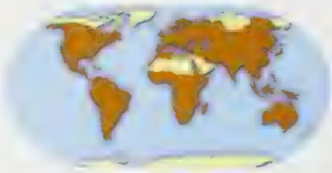
The São Tomé caecilian (*Schistometopum thomense*) (below) is viviparous. The eggs develop in safety in the oviducts Upon hatching, the larvae feed on nutrient-rich fluids secreted by glands in the oviducts for 7–10 months. The bright coloration of this species is a warning to potential predators that its skin secretions make it unpalatable

*Trade-off*

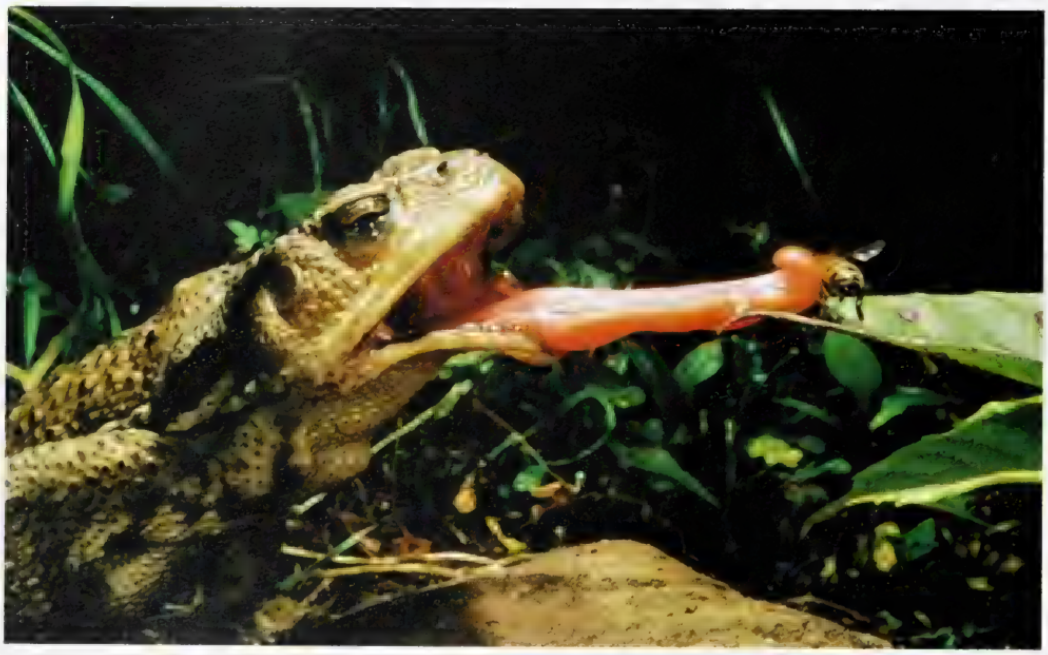
# FROGS AND TOADS

| | |
|---|---|
| CLASS | Amphibia |
| ORDER | Anura |
| FAMILIES | 29 |
| GENERA | 338 |
| SPECIES | 4,937 |

Anuran is the collective term for this group of tailless amphibians. This is the largest order of amphibians, with nearly 5,000 known species. Anurans come in all shapes and sizes, from the tiny Brazilian Izecksohn's toad (*Psyllophryne didactyla*), which is less than half an inch (1 cm) long, to the African goliath frog (*Conraua goliath*), which is 12 inches (30 cm) long and weighs 7½ pounds (3.3 kg). Frogs and toads are easily identified by their long hindlegs, short trunk, moist skin, and lack of tail. Anurans are the only amphibians that are extremely vocal when breeding. The largest genus of frogs—*Eleutherodactylus* (rain frogs)—is also the largest genus of all vertebrates.



**Distribution** Frogs and toads occur on all continents except Antarctica. More than 80 percent of species are tropical; at one site alone, 67 species have been recorded. Two species extend north of the Arctic Circle



**Flying frogs** The Java flying frog (*Rhacophirus reinwardtii*) has broad webs of skin between its toes, allowing it to parachute between trees or guiding it in a controlled fall to another branch. This adaptation is important for life in the rain-forest canopy

**Tongue lashing** Frogs and toads have long, sticky tongues, like the Japanese toad (*Bufo japonicus*) (above), which they use to capture prey. Once the insect is inside the mouth, the toad blinks its eyes and the eyes push the food out of the mouth and down the throat. Males also use their tongues in combat, lashing them into the eyes of other males in territorial battles or in bouts over access to a female

**Frog skeleton** Anurans have a shortened vertebral column of nine or fewer vertebrae. The epipodial elements of both fore and hindlimbs are fused; also, the ankle is elongated and made up of two fused elements. The postsacral vertebrae are uniquely fused into a rod-shaped urostyle. The long hindlimbs give frogs the [illegible] to propel themselves forward. A short, compact body is easier to move forward. The reinforced pectoral girdle and [illegible] are used to absorb the shock of landing.

## SINGING FOR THEIR LIVES

A notable feature of frogs and toads is the voices of the males calling for mates. These calls herald spring in the temperate zone and the onset of the rainy season in the tropics. Each species of frog has a specific call that distinguishes it from all other species. Females can assess the size of the male, and thus his fitness, by the tone of his call. Only males call, and females come to the calling male to mate. These calls also have the disadvantage of attracting some predators, notably bats.

In some species, calling sites are at a premium and males defend them against other calling males. To avoid confrontations, satellite males wait silently near the calling male in hopes of intercepting a gravid female before she reaches him. This lessens their chance of being eaten by a bat, and reduces the energy lost by calling or by fighting with the dominant male.

The above are characteristics of frogs with long breeding seasons. Many other species are explosive breeders, coming to the breeding ponds with the first heavy rains, breeding by the thousands for 2–3 days, and then retreating until the following year. These species

**Calling for a mate** During the breeding season, male frogs and toads call to attract the females to mate. Each species has a distinct attraction call. This natterjack toad (*Bufo calamita*) (above) has his gular sac inflated and is making a trilling sound

**Energy transfers** The northern leopard frog (*Rana pipiens*) (right) leaps to escape a predator. Frogs and tadpoles transform the energy in their food (algae, detritus, and insects) into larger packets of energy that are then available to bigger predators

usually have loud, carrying calls and lay thousands of small eggs. To avoid predation of their eggs by aquatic predators, many species of tree frogs (*Hylidae*) lay their eggs in vegetation overhanging their breeding ponds. When the eggs hatch, the tadpoles fall into the water, where they complete their development. Other species of casque-headed tree frogs (*Osteocephalus*) lay a few large fertilized eggs in tree holes. The female returns regularly to deposit unfertilized eggs in the nest to feed her tadpoles. Many species of poison frogs (*Dendrobatidae*) guard their eggs in terrestrial nests and, upon hatching, carry their tadpoles to the water, or in some cases up trees and into bromeliads. Many species of *Eleutherodactylus* lay 15–25 large yolked eggs in terrestrial nests, the eggs having direct development. Midwife toads, Surinam toads, and gastric-brooding frog females carry the eggs with them until they hatch into small frogs. Other *Leptodactylid* and *Rhacophorid* frogs build foam nests to deposit their eggs and rear their tadpoles.

Frogs are indicators of environmental pollution. Since the 1970s, there has been growing worldwide evidence that frog populations are declining on a massive scale and that many species are going extinct, even though their populations appear to be within pristine areas. The decline may be the result of a number of factors, including pollution, pesticides (such as DDT), herbicides (such as Atrizine), road salts, UV radiation, global warming, lower rainfall, or lower humidity. At present, the fungus chytridiomycosis seems to be the greatest threat. The fungus, which probably originated in Africa, invades the skin and lowers the frogs' immune system so they are more susceptible to diseases.

### CONSERVATION WATCH

The 342 species of anurans on the IUCN Red List are categorized as follows:

| | |
|---|---|
| 7 | Extinct |
| 27 | Critically endangered |
| 27 | Endangered |
| 64 | Vulnerable |
| 1 | Conservation dependent |
| 15 | Near threatened |
| 67 | Data deficient |
| 134 | Least concern |

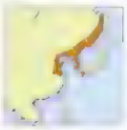
## FACT FILE

**Brown New Zealand frog** Males of this species do not have a prominent breeding call. Call notes are made by resonance frequencies in the head and body, not by the vibration frequency of the vocal cords

- Up to 2 in (5 cm)
- Terrestrial
- Spring
- Vulnerable

Stephens & Maud Islands (New Zealand)

**Oriental firebelly toad** This toad is one of the most common in its range, constituting up to a third of the total anurans at some localities. The density at breeding sites can reach three toads per square foot (nine toads per sq. m)



- Up to 2½ in (6 cm)
- Terrestrial
- Summer
- Common

Russia, Korea, China

**Tailed frog** This frog has no breeding call. Its "tail"—used for internal fertilization in fast-moving streams—is unique among anurans. Eggs are deposited in strings under rocks in streams. Tadpoles take 1–4 years to metamorphose to juveniles, and then 7–8 years to first breeding

- Up to 2 in (5 cm)
- Terrestrial, aquatic
- Summer
- Common

North America

## ANURAN FERTILIZATION

Fertilization of the eggs usually occurs when the frogs are in amplexus. As the female deposits her eggs, males release sperm above them in the water. The frogui and some other terrestrial species achieve internal fertilization by cloacal apposition, only the tailed frog has an intromittent organ.

***Frogs in amplexus***

The female grasps the male as he fertilizes the eggs, ensuring the survival of the species.

Shaping frog
*Atympanophrys shapingensis*

Malayan horned frog
*Megophrys nasuta*

Common parsley frog
*Pelodytes punctatus*

Surinam toad
*Pipa pipa*

Eggs embedded in back

Mexican spadefoot toad
*Spea multiplicata*

Mid-dorsal red-orange stripe

Mexican burrowing toad
*Rhinophrynus dorsalis*

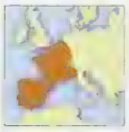
Mueller's clawed frog
*Xenopus muelleri*

Cape clawed frog
*Xenopus gilli*

Syrian spadefoot toad
*Pelobates syriacus*

## FACT FILE

**Common parsley frog** Male parsley frogs can be heard calling from below the surface of the water. The tadpoles are larger than the adult frogs, at up to 2½ in (6 cm) in length. The eggs are laid in strings across aquatic plants



Up to 2 in (5 cm)
Terrestrial, aquatic
Spring
Common

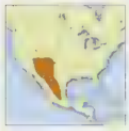
Iberia, France, W. Belgium, N.W. Italy

**Surinam toad** During amplexus, the female releases eggs one at a time The male fertilizes and embeds each egg in the skin of her back, where the eggs sink in and form a honeycomb of pockets. After 3–4 months, froglets emerge from her back.

Up to 8 in (20 cm)
Aquatic
Spring
Common

N. South America

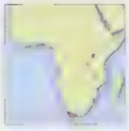
**Mexican spadefoot toad** Spadefoots are nocturnal during the summer rainy season, when they are breeding. The rest of the year, they occupy burrows that they dig in the soft earth.



Up to 2 in (5 cm)
Terrestrial
Summer
Common

S.C. USA, N. Mexico

**Cape clawed frog** Modification of the acid, black-water ponds inhabited by this species allowed the invasion of the common clawed frog (*Xenopus laevis*) The two are interbreeding, producing sterile hybrids and further driving this species toward extinction



Up to 2 in (5 cm)
Aquatic
Winter
Vulnerable

S.W. South Africa

**Mexican burrowing toad** [illegible] spends most of its lif[illegible] only emerging to br[illegible] rains. Males' bodies are so inflated when calling tha[illegible]

## FACT FILE

**Turtle frog** [illegible]

Up to 2.5 in (6 cm)
Terrestrial, burrowing
[illegible]

[illegible]

**Crucifix toad** This fossorial toad [illegible] Makes call [illegible] small tadpole [illegible] in the water.

[illegible]
[illegible]
[illegible]
Common

[illegible]

**Giant banjo frog** Adults spend daytime hours and dry months buried beneath the surface. Males call while floating on vegetation or concealed in burrows at the water's edge. Oviposition takes place in flooded burrows.

[illegible]
[illegible]
[illegible]
[illegible]

[illegible]

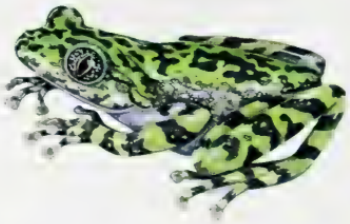
## GASTRIC BROODERS

[illegible]

[illegible]

Red-crowned toadlet
*Pseudophryne australis*

Skeleton ghost frog
*Heleophryne rosei*



Spatulate toes used for climbing rocks

Thomasset's frog
*Nesomantis thomasseti*

Turtle frog
*Myobatrachus gouldii*

Crucifix toad
*Notaden bennetti*

Natal ghost frog
*Heleophryne natalensis*

Giant banjo frog

Differs from the giant burrowing frog (*Heliporus australicacus*) as lacks black spines on the back and throat

Western marsh frog
*Heleioporus barycragus*

Surinam horned frog
*Ceratophrys cornuta*

South American bullfrog
*Leptodactylus pentadactylus*

Active forager, feeding on small prey only

Ornate horned toad
*Ceratophrys ornata*

Budgett's frog
*Lepidobatrachus laevis*

Vizcacheras' white-lipped frog
*Leptodactylus bufonius*

Schmidt's forest frog
*Hydrolaetare schmidti*

Dumeril's striped frog
*Leptodactylus gracilis*

Weeping frog
*Physalaemus biligonigerus*

Sehuenca's water frog
*Telmatobius yuracare*

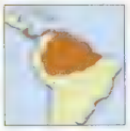
## FACT FILE

**Surinam horned frog** When prey ventures nearby, this frog lurches forward, opening the mouth that dominates the entire top of its head, and swallowing the prey whole

Up to 4¾ in (12 cm)
Terrestrial
Fall rainy season
Common

Amazonia (South America)

**South American bullfrog** The call is a single, loud, whistle-like hoot. Up to 3,000 eggs are laid in a depression in the forest floor. The cannibalistic tadpoles are dispersed to nearby streams or swamps by heavy rains.



Up to 7 in (18 cm)
Terrestrial
Fall
Common

Honduras to Bolivia

**Budgett's frog** This is a large, stout, aquatic frog with a flattened body. The head is large and robust, one-third of the total body length, and broad to accommodate its very wide jaws.

Up to 4 in (10 cm)
Aquatic
Summer
Common

Gran Chaco (Argentina, Bolivia, Paraguay)

## DROUGHT RESISTANCE

During the dry winter months, ornate horned toads are inactive underground, encased in a hard shell composed of layers of unshed skin. This "cocoon" protects the animal from excessive water loss and allows it to survive until the rains arrive. These signal the beginning of the wet summer months in South America, which last from October to February. The heavy rains flood the Gran Chaco and create transient pools for foraging and breeding.

***Digging in*** [illegible]

## FACT FILE

**Coqui** This species gets its name from its high-pitched chirp, which sounds like "co qui." Eggs are laid on land with direct development in the egg. Coquis have been introduced into Florida and Hawaii, United States.

Up to 2¼ in (5.5 cm)
Terrestrial, arboreal
Year round
Common

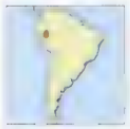
Puerto Rico (Caribbean)

**Barking frog** The breeding call of this species sounds like a dog barking when heard at a distance; close up, it is a guttural "whurr." Females make a screech when grasped. When captured, their bodies puff up immensely.

Up to 3¾ in (9.5 cm)
Terrestrial
Spring
Common

S.W. USA to C.W. Mexico

**Peru robber frog** This species has direct development. The eggs are deposited in moist areas in the leaf litter. The males, which are considerably smaller than the females, call day and night from the forest floor.



Up to 1¼ in (3 cm)
Terrestrial
Fall rainy season
Common

W. Amazonia (Brazil, Bolivia, Peru, Ecuador)

**Lowland tropical frog** Females deposit up to 20 unpigmented eggs in a foam nest. The tadpoles developing in the nest subsist entirely on the egg yolk. Males call from mudflats.

Up to 1¼ in (3 cm)
Terrestrial
Spring
Common

Amazonia (N. South America)

**Gold-striped frog** The flash coloration —bright red spots in the groin and on the rear of the thighs—is displayed when the frog moves. Its coloration mimics that of the spotted-thighed poison frog (*Epipedobates femoralis*). Eggs are deposited in foam nests.

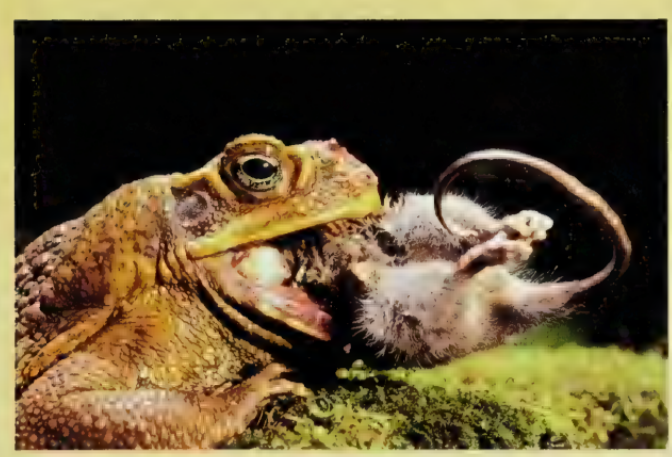
Up to 2 in (5 cm)
Terrestrial
[illegible]
[illegible]

[illegible]

# ADVANCE OF THE CANE TOAD

**Toad nightmare** The cane fields did not have proper daytime cover so the introduced toads dispersed into the countryside. They are now so abundant that gardens become a moving mass of toads at night and the roads are slippery with splattered bodies.

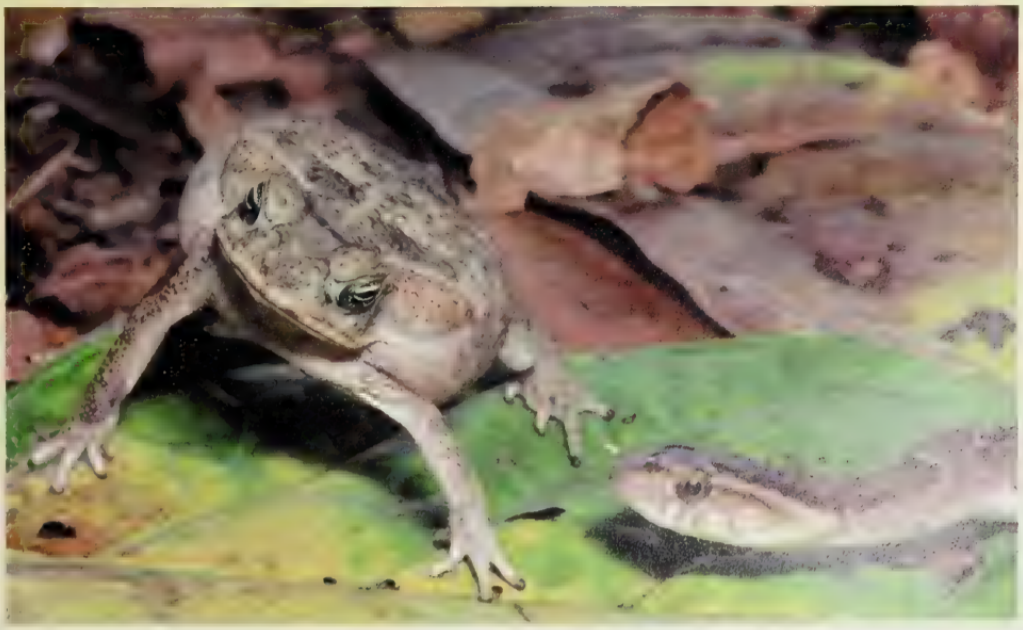
Successful stories of the cane toad (*Bufo marinos*) (also known as the marine toad) being introduced into the sugarcane fields of Puerto Rico to control insect pests convinced the sugarcane growers in Queensland, Australia, to import and breed 100 adult toads. In 1935, they released 62,000 subadults in Queensland to control the grayback cane beetle (*Dermolepida albohirtum*). Since the neotropical cane toad has no natural predators in Australia, populations have reached plague proportions. The toads adapted well to feeding on all animals smaller than themselves, even competing with dogs for the rations in their bowls. Studies in Brazil are yet to come up with a solution.



**Cane toad poison** When cane toads are threatened, they inflate their bodies and begin sweating a milky, latex-like liquid from the paratoid glands. In extreme cases, the secretions can be projected up to 3 feet (92 cm) toward the aggressive attacker, but are not toxic unless ingested. The poison has been used as a hallucinogenic drug

**Breeding** The cane toad breeds year-round in Australia in temporary pools, stock tanks, lakes, and streams. The prolific toads are capable of producing up to 13,000 eggs at a time. Their tadpoles transform rapidly and have minimal habitat requirements: algae and water. Although cane toads take several years to mature, they can live for over 20 years. Calling cane toads interfere with the breeding choruses of native frogs

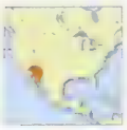
**Indiscriminate eaters** The cane toad grows up to 9 inches (23 cm) long and can weigh over 2¼ pounds (1 kg). It eats nearly anything smaller than itself, including many beneficial frogs. The cane toad above is swallowing a pygmy possum.



**Fatal meal** The cane toad's paratoid glands contain a secretion that is fatal to some animals. The cane toad pictured right has angled its paratoid glands toward the approaching snake. Populations of Australian snakes that normally consume native anurans are diminishing because they die from swallowing cane toads. This is also a problem for other indigenous animals Birds, dingos, monitor lizards, and other anurans see the cane toad as possible prey. Fishes die from ingesting the toxic tadpoles. And the problem is not restricted to areas into which it has been introduced: in South America, a group of Peruvian Indians is believed to have perished after eating a soup made from cane toad eggs

## FACT FILE

**Colorado river toad** The skin glands of these toads produce a toxin that can cause intoxication and hallucination in humans, and is a controlled substance in the United States, where people have been arrested for milking toads



Up to 8 in (20 cm)
Terrestrial
Summer
Common

S.W. USA & N.W. Mexico

**Common Asian toad** Once common, this species is declining due to habitat alteration and loss, caused by drought, deforestation, drainage of habitat, pesticides, fertilizers, and pollutants

Up to 6 in (15 cm)
Terrestrial
Summer
Declining

S.E. Asia

## AMPHIBIAN EGG

Amphibian embryos have gelatinous membranes around them, but lack the protective amnion present in reptiles. Since eggs also lack shells, they must be protected from desiccation. Eggs contain nutrients for the tadpoles to develop into free-swimming larvae. Eggs of some species have enough yolk to nourish the embryos until they hatch as miniature adults

***Tadpole developing in egg***
*Amphibians must either deposit their eggs in water or in moist places to avoid desiccation*

## CONSERVATION WATCH

The 18 species of Bufonidae on the IUCN Red List are categorized as follows:

- 1 Critically endangered
- 6 Endangered
- 6 Vulnerable
- 2 Near threatened
- [illegible] Data deficient

1 Cururu toad *Bufo paracnemis*
2 Colombian giant toad *Bufo blombergi*
3 Cane toad *Bufo marinus*
4 Cameroon toad *Bufo superciliaris*
5 Square-marked toad *Bufo regularis*
6 Tschudi's Caribbean toad *Bufo peltocephalus*
7 Colorado river toad *Bufo alvarius*
8 Berber toad *Bufo mauritanicus*
9 Common Asian toad *Bufo melanostictus*

Everett's Asian tree toad
*Pedostibes everetti*

Sonoran green toad
*Bufo retiformis*

Horned toad
*Bufo ceratophrys*

South American common toad
*Bufo margaritifer*

Red toad
*Schismaderma carens*

Oak toad
*Bufo quercinus*

Red-spotted toad
*Bufo punctatus*

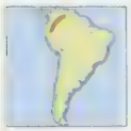
Two color morphs of harlequin frogs

Green toad
*Bufo viridis*

Harlequin frog
*Atelopus varius*

## FACT FILE

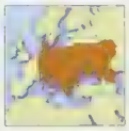
**Horned toad** This diurnal toad lives on the forest floor where it forages for termites and breeds in forest streams



Up to 3¼ in (8.2 cm)
Terrestrial
Unknown
Common

N.W. Amazonia (South America)

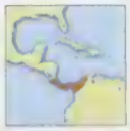
**Green toad** Green toads form dense populations in areas altered by people, and these are often much higher than in adjacent natural habitats. They prefer burrows and live in the burrows of rodents. Abundance can reach more than 100 individuals per 1,075 square feet (100 sq. m)



Up to 4¾ in (12 cm)
Terrestrial
Spring
Common

Europe to Asia

**Harlequin frog** No courtship has been reported for this species. Amplexus is prolonged; females carry males on their backs from a few days to over a month until about 20 eggs are laid in water



Up to 2 in (5 cm)
Terrestrial, aquatic
Fall
Declining

S. Costa Rica, Panama, N. Colombia

## TOADS VERSUS FROGS

In Europe and North America, toads (family Bufonidae) have short legs for hopping, dry warty skin, and are terrestrial. Frogs (family Ranidae) have long, slender legs for leaping great distances, moist skin, and are aquatic However, the use of the terms "frog" and "toad" depends on the region of the world you are in. In Africa, the smooth and moist-skinned aquatic Cape clawed frog (*Xenopus gilli*) is called a clawed toad

*To kiss a toad*

## FACT FILE

**Australian lace-lid frog** This frog has huge eyes with vertically elliptical pupils and a lower eyelid with a golden [illegible] It is found on rocks and vegetation in fast-flowing rocky streams in rain forest up to 3,900 feet (1,200 m)

Up to 2½ in (6 cm)
Arboreal
Spring, summer
Endangered

N.E. Australia

**Southern bell frog** Males call while floating on the water. The call is a low growl lasting about a second. The eggs are deposited in a floating jelly that later sinks. They feed on other frogs and even their own species

Up to 4 in (10 cm)
Terrestrial, aquatic
Summer
Locally common

S.E. Australia & Tasmania

**Short-footed frog** This is a robust, burrowing frog with striking and highly variable markings. The back is dark brown with silver-brown blotches. The frog usually also has a silver-brown stripe down the back and a white belly

Up to 2 in (5 cm)
Terrestrial, burrowing
Unknown
Common

N.E. Australia

**Paradox frog** This frog has large webbed feet and extremely slippery skin. The tadpoles are three times as large as the adults, up to 10 inches (25 cm) in length

[illegible]

**Water-holding frog** This species [illegible] the long dry periods, which can [illegible] several years long, in burrows [illegible] It surrounds itself [illegible] chamber, formed [illegible] layers of its skin

[illegible]

Australian lace-lid frog
*Nyctimystes dayi*

Dainty green tree frog
*Litoria gracilenta*

Southern bell frog
*Litoria raniformis*

Blue Mountains tree frog
*Litoria citropa*

White's tree frog
*Litoria caerulea*

Green and golden bell frog
*Litoria aurea*

Short-footed frog
*Cyclorana brevipes*

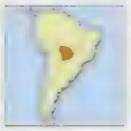
Paradox frog
*Pseudis paradoxa*

Extensively webbed feet

Water-holding frog
*Cyclorana platycephala*

## FACT FILE

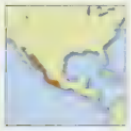
**Painted-belly leaf frog** This tree frog coats itself with a waxy secretion to keep in moisture. It falls flat on a leaf and then rolls it up with this waxy skin secretion.



Up to 10 in (8.8 cm)
Arboreal
Rainy season
Common

Gran Chaco (N. Paraguay, N. Argentina, E. Bolivia, S. Brazil)

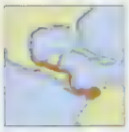
**Shovel-headed tree frog** The skin of this frog's head is fused to the cranial bone. When it retreats, such as holes in trees or rock crevices, the frog plugs the hole with its head to prevent desiccation and predation.



Up to 3 in (7.5 cm)
Terrestrial, arboreal
Summer
Common

W. Mexico

**Red-eyed tree frog** This species lays its green eggs on vegetation or rocks overhanging temporary ponds. The tadpoles hatch and fall into the water to complete development. The males become sexually mature after a year.



Up to 3 in (7.5 cm)
Arboreal
Summer
Common

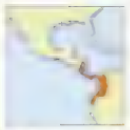
S. Mexico to Colombia

## FROG FEET

Frogs have four digits on the forelimbs and five on the hindlimbs. The shapes vary depending on their habits: fully webbed for swimming, or toe pads for climbing, or modified claws with extra tubercules for digging.

## FACT FILE

**Nicaragua giant glass frog** This [illegible] species—using a three-tone series of high-pitched "clicks"—from above [illegible] in amounts [illegible] to leaves that overhang the streams. Tadpoles attach to rocks with their suction mouths.



- Up to 1 in (2.5 cm)
- Arboreal
- [illegible]
- [illegible]

N Nicaragua to Colombia & Ecuador

**Barking tree frog** This frog gets its name from its loud raucous call of nine or ten notes, from high in the treetops during a temporal call. Its breeding call is a single "croak" or "bark." The female deposits eggs singly on the bottom of the breeding pond.

- Up to 2½ in (6 cm)
- Terrestrial arboreal
- Spring, summer
- Mountain

[illegible]

**European tree frog** This tree frog is declining in western and central Europe due to loss of habitat, habitat isolation, pollution, and climate change.

- Up to 2 in (5 cm)
- Terrestrial arboreal
- Lowlands
- [illegible]

[illegible]

**Marsupial frog** During amplexus, the male pushes the fertilized eggs into a pouch on the back of the female. Young development takes place in the pouch without a tadpole stage.

- Up to 2 in (5 cm)
- Terrestrial arboreal
- [illegible]
- [illegible]

[illegible]

## CONSERVATION WATCH

The 72 species of Hylidae on the IUCN Red List are categorized as follows:

- 6 Critically endangered
- [illegible] Endangered
- [illegible] Vulnerable
- [illegible] Near threatened
- [illegible] Data deficient
- [illegible] Least concern

# TREE FROGS

**Striking skin** The Bereis' tree frog has a variable color pattern resembling the markings of a giraffe; other tree frogs are less striking. Large toe pads and loose belly skin allow this frog to stick to leaves and other smooth surfaces when climbing and searching for prey.

The family Hylidae—tree frogs—comprises 855 species in 42 genera, distributed primarily in North America, South America, and Australia, and to a lesser extent in Europe and Asia. Tree frogs range in size from the half an inch (12 mm) adult javelin frog (*Litoria microbelos*) to the 5½ inch (14 cm) Hispaniola tree frog (*Hyla vasta*). Most hylids are arboreal, but some are terrestrial, aquatic, or burrowing. Most possess adhesive toe pads, which allow them to cling to any surface. Almost all are very flattened and streamlined, with long legs that are useful for leaping from branch to branch. Tree frogs have horizontally elliptical pupils, with the exception of the Phyllomedusids, which have vertical pupils.

**Burrowing habits** The burrowing tree frog (*Pternohyla fodiens*) is found in many habitats subject to seasonal inundation. They are well adapted for burrowing and spend the dry season in a dormant state beneath the surface. They will only breed after heavy rain.

**Harlequin flying tree frog** The harlequin flying tree frog (*Rhacophorus pardalis*) is found from 650–5,575 feet (200–1,700 m) and has a 2½ inch (6.5 cm) snout–vent length. They lay up to 50 eggs in a foamy mass on leaves suspended in the trees above ponds between March and May and can be found in the Philippines, Borneo, and Sumatra.

**Safe hands** The brown-belly leaf frog (*Phyllomedusa tarsius*) is nocturnal and arboreal in primary and secondary rainforests in the Amazon. The first digit on the front foot is opposable, so these frogs can grasp small branches like a primate as they crawl slowly through the canopy oblivious to wind and rain. They have rounded paratoid glands extending at least to mid-body.

*Hanging on* [illegible]

**Reproduction in the trees** Males have species-specific vocalizations that they use to attract gravid females. Amplexus stimulates the females to deposit eggs, usually in water, where they hatch into free-swimming tadpoles. Many species deposit their eggs in overhanging vegetation, where the eggs hatch, the females fall into the water to finish their development. Some species cannot feed kept in captivity and the tadpoles develop [illegible] [illegible]

## FACT FILE

**Nosy Be giant tree frog** This species [illegible] single whistling note that lasts [illegible] 55–65 milliseconds. The call [illegible] repeated over a hundred times a [illegible]. Their hands lack webbing and the feet are barely webbed

Up to [illegible]
Terrestrial, arboreal
[illegible]
Common

N. & Madagascar

**Dotted humming frog** This frog exists mutualistically with tarantulas in their burrows, feeding on ants that prey on tarantula eggs. At night, the frogs sit between the legs of the spiders at the mouths of their burrows

Up to 1 in (2.5 cm)
Terrestrial
Summer
Common

E. Ecuador, S.E. Peru, N.W. Bolivia

**Tomato frog** The bright red coloration of this frog acts as a clear warning to potential predators that it is a toxic meal. A white, sticky fluid secreted from the skin deters snakes and can produce an allergic reaction in humans.

Up to 4 in (10 cm)
Terrestrial, aquatic
Summer
Vulnerable

N.E. Madagascar

## RAIN FROGS OF AFRICA

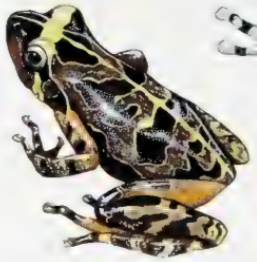
Rain frogs (genus *Breviceps*) have short heads and stout bodies. They appear above ground only during torrential rain. Males have loud, bellowing calls that can be heard from great distances, and sticky skin secretions that attach them to the females during amplexus. [illegible] their eggs underground, and the [illegible] frogs develop without any [illegible] water.

***Puffed up like a balloon***

[illegible]

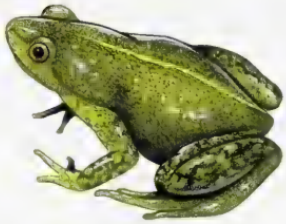
Ornate rice frog
*Microhyla ornata*

Nosy Be giant tree frog
*Platypelis milloti*

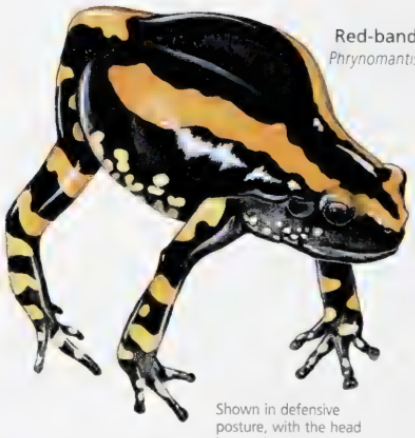


Red rain frog
*Scaphiophryne gottlebei*

Dotted humming frog
*Chiasmocleis ventrimaculata*



Red-banded frog
*Phrynomantis bifasciata*



Shown in defensive posture, with the head lowered and the rear legs extended

Muller's termite frog
*Dermatonotus muelleri*

Great Plains narrow-mouthed toad
*Gastrophryne olivacea*

Tomato frog
*Dyscophus antongili*

Malaysian narrow-mouthed toad
*Kaloula pulchra*

Males are patterned like females, but are [illegible]

Brilliant-thighed poison frog
*Allobates femoralis*

Harlequin poison frog
*Dendrobates histrionicus*

Redback poison frog
*Dendrobates reticulatus*

Trinidad poison frog
*Mannophryne trinitatis*

Yellow-headed poison frog
*Dendrobates leucomelas*

Strawberry poison frog
*Dendrobates pumilio*

Lehmann's poison frog
*Dendrobates lehmanni*

Has enlarged toe pads for climbing to bromeliads

Green and black poison frog
*Dendrobates auratus*

Blue poison frog
*Dendrobates azureus*

Golden poison frog
*Phyllobates terribilis*

## FACT FILE

**Harlequin poison frog** The male calls from branches up to 3 feet (92 cm) high. The male often sits on the back of the female on the way to the oviposition site. Their complex courtship ritual, which lasts for 2–3 hours, involves a sequence of sitting, bowing, crouching, touching, and circling behavior patterns.

Up to 1½ in (4 cm)
Terrestrial, arboreal
Rainy season
Common

Colombia, Ecuador

**Redback poison frog** Females lay either two or three eggs, ⅛ inch (2 mm) in diameter. Although they are primarily found on the forest floor, males hop up tree trunks carrying one or two tadpoles to deposit in bromeliads.

Up to ¾ in (2 cm)
Terrestrial, arboreal
Rainy season
Common

N.E. Peru, W. Brazil

**Blue poison frog** Females lay eggs in water for the males to fertilize. The males usually guard the eggs until the tadpoles develop after about 12 days. At 12 weeks, the tadpoles metamorphose into grown frogs.

Up to 2 in (5 cm)
Terrestrial
Rainy season
Uncommon

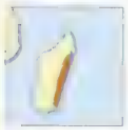
Suriname

## POISON-ARROW FROGS

Indigenous tribes coat their dart tips with the secretions of Dendrobatids, or poison-arrow frogs. This toxin blocks neural transmission at the acetylcholine receptor of the neuro-muscular junction, which causes paralysis or even death. To produce these skin toxins, the frogs need to consume ants that produce formic acid.

## FACT FILE

**Madagascar reed frog** These frogs are common in dunes, savanna, and deforested habitats of the east coast of Madagascar. They are active at night in the vegetation above, or at the edge of, shallow ponds and swamps. During the day they take refuge near pools, submerging when disturbed by a potential predator. Eggs are laid in the water



Up to 1¼ in (4 cm)
Terrestrial
Year round
Common

Madagascar

**Tulear golden frog** The species was described from a series of specimens obtained via the pet trade, for which it is currently subject to intense collecting at the beginning of the rainy season (October to December). During the first rains, these frogs, which breed explosively, come out from their refuges and are very easy to capture

Up to 1¼ in (3.2 cm)
Terrestrial
Rainy season
Uncommon

Madagascar

**Weal's running frog** Males call from elevated positions in vegetation, on the banks of, or partly submerged among, plants in a pond. The voice is a coarse, loud rattle, similar to the creak of a cork being removed from a wine bottle. One call, lasting about half a second, is emitted every 3–5 seconds

Up to 1¾ in (4.4 cm)
Terrestrial
Rainy season
Common

E. & S.E. South Africa

## CONSERVATION WATCH

**In danger** At least 27 species of anurans are listed on the IUCN Red List as critically endangered, many because of direct encroachment of humans, habitat destruction, water pollution, and use of herbicides and pesticides. But even populations of the golden toad (*Bufo periglenes*), which lives in protected reserves on mountain tops, have recently plummeted. This may be due to global warming and forest cutting, which affect the rainfall patterns that maintain the misty environment in montane cloud forests

Red-eared frog
*Rana erythraea*

African bullfrog
*Pyxicephalus adspersus*

European common frog
*Rana temporaria*

Pickerel frog
*Rana palustris*

Malaysian frog
*Rana luctuosa*

Marsh frog
*Rana ridibunda*

Pig frog
*Rana grylio*

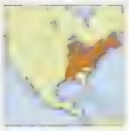
Dorsum has two rows of square chocolate-colored blotches, while the leopard frog, for which it has been mistaken, usually has round blotches

Amazon river frog
*Rana palmipes*

Bullfrog
*Rana catesbeiana*

## FACT FILE

**Pickerel frog** These frogs produce toxic skin secretions that irritate human skin and can be fatal to small animals, especially other amphibians. Many frog-eating snakes avoid these frogs. Leopard frogs (*Rana pipiens*) mimic the color pattern of pickerel frogs in areas of sympatry to avoid snake predation.



Up to 3 in (7.5 cm)
Terrestrial, aquatic
Spring
Common

E. USA

**Amazon river frog** This aquatic species forages day and night along the edges of rivers, permanent pools, and lakes. They consume invertebrates and vertebrates, such as insects, fishes, other frogs, and small birds, both in and out of the water.

Up to 4½ in (11.5 cm)
Aquatic
Rainy season
Common

Central America to Peru & Brazil

**Bullfrog** This large frog eats anything that moves that it can swallow. This species was introduced into the western United States, where it reduced or extirpated local species of amphibians and reptiles. Tadpoles take 2 years to develop and the adults several years to mature.

Up to 8 in (20 cm)
Aquatic
Summer
Common

E. USA

## MASS SPAWNING

The European common frog mates en masse in 3 days in spring, each laying about 400 black eggs in gelatinous clusters. The eggs absorb UV radiation, which increases the water temperature and thus the eggs' development [illegible]

Group sex

## FACT FILE

**Singapore wart frog** [illegible]

[illegible]

**Cape dainty frog** [illegible]

South Africa

## ANURAN DEFORMITIES

[illegible]

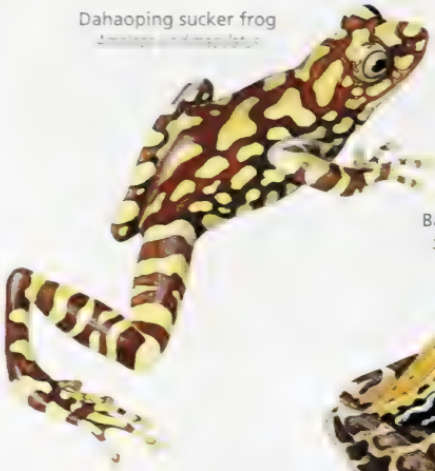
*Multi-legged frog*

[illegible]

## CONSERVATION WATCH

The 49 species of Ranidae on the IUCN Red List are categorized as follows:

- 3 Extinct
- [illegible] Critically endangered
- 6 Endangered
- [illegible]
- 4 Near threatened
- [illegible]
- [illegible]



Dahaoping sucker frog
*Amolops [illegible]*

Borneo splash frog
*Staurois tuberilinguis*

Banded stream frog
*Strongylopus bonaspei*

Mascarene Ridge frog
*Ptychadena mascareniensis*

Cape dainty frog
*Cacosternum capense*

Eucotyl glands on the back and sides

Striped sand frog
*Tomopterna cryptotis*

Singapore wart frog
*Limnonectes malesianus*

African ornate frog
*Hoplobatrachus ornatus*

Spotted snout-burrower
*Hemisus guttatus*

Painted Indonesian tree frog
*Nyctixalus pictus*

Bush squeaker
*Arthroleptis wahlbergii*

Java whipping frog
*Polypedates leucomystax*

Warty tree frog
*Theloderma asperum*

Distinctive black membranes between the heavily webbed toes

Abah River flying frog
*Rhacophorus nigropalmatus*

Madagascar bright-eyed frog
*Boophis madagascariensis*

Hairy frog
*Trichobatrachus robustus*

African gray tree frog
*Chiromantis xerampelina*

Bongon whipping frog
*Polypedates otilophus*

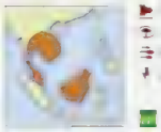
Highly vascularized papillae on the hindlimbs

## FACT FILE

**Java whipping frog** This is one of the more successful frogs in modern times, as it adapts well to human environments. Their loud calls are found inside bathrooms, water tanks, drains, or any damp spot.

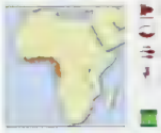
SE Asia

**Abah River flying frog** The female beats a body fluid into a foam in a nest of twigs and leaves above the water. When the fertilized embryos hatch into tadpoles, the nest deteriorates and they drop into the water.



Indonesia, Malaysia, Thailand

**Hairy frog** The dermal papillae of males increase the surface area for respiration. Males need an enlarged respiratory surface due to their small lungs and robust body. Tadpoles are carnivorous and possess teeth.



Guinea, Cameroon, Congo, Nigeria

## CONTROLLED FALLING

Frogs possessing expanded webbing on the feet are able to fall in a controlled fashion to avoid predators or move about. They can adjust the impact and control the direction of their fall.

# FISHES

# FISHES

PHYLUM Chordata
SUBPHYLUM Vertebrata
CLASSES 5
ORDERS 62
FAMILIES 504
SPECIES 25,777

With more than 25,000 described so far, and perhaps several thousand more still to be identified, fishes comprise over half of all living vertebrate species. They first evolved about 500 million years ago in fresh water and now exploit almost every aquatic habitat from polar seas to tropical ponds. Some even live briefly on land. This diverse group includes tiny gobies ¾ inch (1 cm) long and massive 40 foot (12 m) whale sharks, drab wobbegongs and vibrantly colored butterfly fish, fiercely predatory great white sharks and placid algae-grazing parrotfish. Five classes survive today: hagfishes, lampreys, cartilaginous fishes, lobe-finned fishes, and ray-finned fishes.

**Gill-breathing** Water enters the mouth and passes over feather-like gill filaments that are richly endowed with capillaries. Each filament has many folds, creating an enormous area for gas exchange. As blood and water pass closely in opposite directions, oxygen diffuses into the capillaries as carbon dioxide is expelled.

## AQUATIC ADAPTATIONS

Many adaptations in the fishes have been driven by water's physical and chemical properties. The basic streamlined torpedo fish body shape, for example, has evolved to move through this medium, which is 800 times denser than air.

Forward motion in most species is created by oscillations of the tail fin and body, the other fins providing stability and maneuverability. The demands of such movements mean swimming muscles make up about half the body weight of most fishes. Maneuverability is enhanced in water by neutral buoyancy (weightlessness), achieved in most fishes by a swim bladder, an internal gas-filled sac.

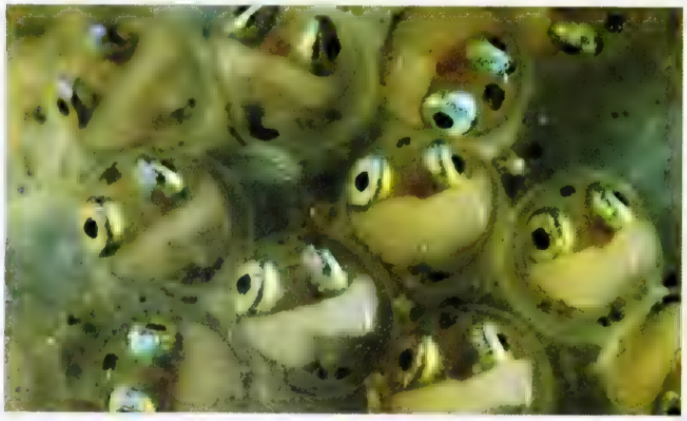
The aquatic medium has also propelled the evolution of specialist sensory equipment, such as the lateral line organs. These usually run the length of the body and detect tiny changes in the surrounding water pressure, assisting in both prey location and avoiding obstacles.

Some fishes reproduce by means of internal fertilization and produce live young. Water, however, provides for the ready mixing of sex cells and dispersal of offspring and so most fishes lay eggs that are fertilized and hatched outside the female.

Fishes are the only vertebrates with true fins and most use them to swim. In some, however, these appendages allow for "walking," while in others they accommodate brief bouts of "flight."

One of the most important early evolutionary events in fishes, and indeed all vertebrates, was the development of jaws. This is thought to have first occurred in the fishes about 450 million years ago. Jaws probably evolved from gill arches. It is thought one of the anterior arches became fused to the skull, its upper section developing into the top jaw, the lower section developing into the bottom jaw.

The earliest fishes were filter feeders, but the evolution of jaws expanded options considerably and underpinned the enormous diversification of the group that followed.



**Fishes-in-waiting** Many fishes emerge [illegible] laid eggs as larvae to [illegible] habitats to their parents [illegible] metamorphosing into adult form [illegible] (above), young [illegible] hatch in the egg and [illegible] appearance of tiny adults.

**Leaping devil** [illegible]

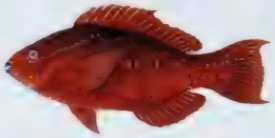
**Extreme specialist** The honeycomb cowfish (*Acanthostracion polygonius*) (right) belongs to an advanced group that has lost the typical torpedo-shaped streamlining. The plate-like armor prevents body movement but the fins are able to facilitate finely controlled "hovering."

# HERMAPHRODITISM

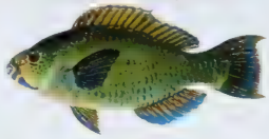
Most fishes are dioecious: they are either male or female from an early age and remain that way throughout life. Hermaphroditism (where individuals possess both male and female sex organs during their lives) is, however, widespread in the group, much more so than among other vertebrates. In some species, individuals are sequential hermaphrodites, changing gender once they reach a certain size or when there is a shortfall of one sex or the other. Less common are simultaneous hermaphrodites, which can perform as either sex at the same time. Hermaphroditism tends to be more prevalent among fishes of lower latitudes. The fish life on tropical coral reefs, in particular, is noted for the phenomenon.

**Sex-changing eel** [illegible] *Rhinomuraena quaesita* are protandrous hermaphrodites: males become females. The male will turn longer below as it matures into a female.

Juvenile: not sexually active



Initial phase: usually female



Terminal phase, always a mature male

**Replaceable males** Hermaphroditism is common in parrotfishes. A dominant male often maintains a harem of females but, if he disappears, the largest and most aggressive female undergoes a sex change accompanied by a dramatic color change, all in a matter of weeks

**Dominance changeover** Among [illegible] Dendrochirus [illegible] are protogynous hermaphrodites, a single dominant male is associated with a small harem of females. In response to the death or removal of the male, the largest female grows larger and their [illegible] color before becoming the dominant male.

*4. Quick change* The sexual transformation is completed within about 10 days and the new male begins courting with the particular [illegible]

*1. Harem life* Female spotbreast angelfish are yellow on their upper surface and pale blue below, with strong black lines defining their tails. Harems usually contain between three and five females

*3. Girl power* [illegible]

*2. Changing colors* When the dominant male disappears, the harem's largest female begins to grow and develop the distinctive coloration of a male: a pale blue body with black stripes.

# JAWLESS FISHES

| | |
|---|---|
| SUPERCLASS | Agnatha |
| CLASSES | 2 |
| ORDERS | 2 |
| FAMILIES | 2 |
| SPECIES | 105 |

These were the first fishes and most became extinct by about 360 million years ago. The two surviving groups—hagfishes and lampreys—are probably only distantly related to each other. They comprise 105 species. All lack scales and jaws and have cartilaginous skeletons. True fins are either absent or poorly developed. Hagfishes are eel-like in appearance and produce copious quantities of mucus from slime glands along the length of the body, possibly for defensive reasons. These scavengers of dead and dying fishes and invertebrates have photoreceptors but do not have true eyes or a larval phase. Lampreys have functional eyes and a long larval phase. Larval lampreys are filter feeders but most adults are external parasites on other fishes.

**Widespread curiosities** Hagfishes and lampreys are found in temperate waters of the Northern and Southern hemispheres and in cool, deep waters in parts of the tropics. Although lampreys are found in both fresh and salt water, hagfishes are exclusively marine. Larval lampreys burrow into soft stream and river substrates where they feed by filtering algae, detritus, and microorganisms from the water.

**Serious suckers** Lampreys parasitize other fishes by attaching to their bodies with a toothed oral disk (right). They mainly live on their host's body fluids but sometimes also consume pieces of flesh and even internal body organs. They often cause the death of their hosts. The arrangement of the teeth lining the oral disk and mouth is an important aid to identifying lampreys, which look very similar.

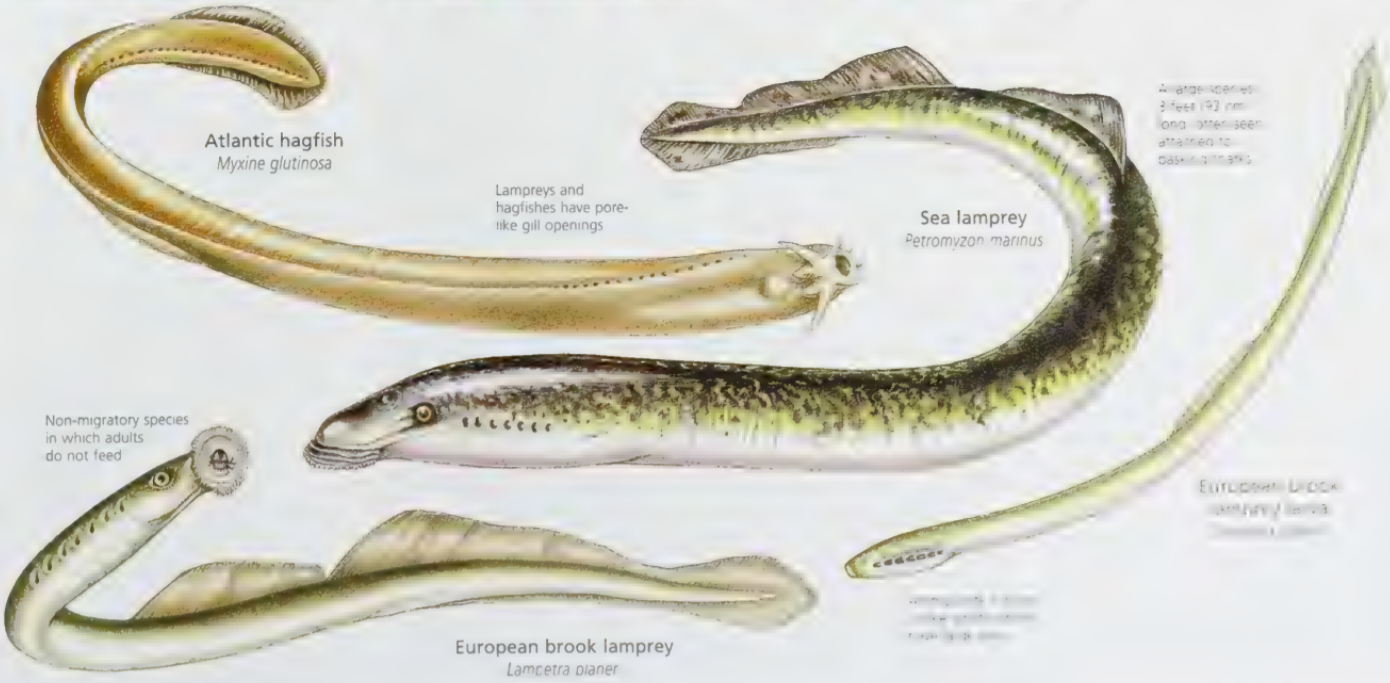
### CONSERVATION WATCH

**Lamprey losses** The IUCN Red List records that the Lombardy brook lamprey (*Lethenteron zanandreai*) is endangered and the Greek brook lamprey (*Eudontomyzon hellenicus*) and non-parasitic lamprey (*Mordacia praecox*) are vulnerable. Habitat destruction is a major threat.

## REPRODUCTION

Hagfish reproduction remains largely a mystery. These fishes begin life as hermaphrodites, later becoming either female or male. They are thought to spawn repeatedly during their lives, each time producing a small number of large eggs—about 1 inch (2.5 cm) long—in toughened cases.

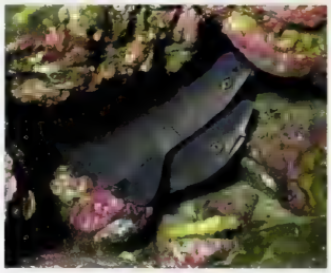
Lampreys only spawn once, producing large numbers of much smaller eggs before dying. They spend their first few years as filter-feeding larvae called ammocoetes. Metamorphosis into young adults usually occurs when they are 3–6½ inches (7.5–16.5 cm) long and takes 3–6 months. Some migrate downstream to the sea.



# SHARKS, RAYS, AND ALLIES

CLASS Chondrichthyes
SUBCLASSES 2
ORDERS 12
FAMILIES 47
SPECIES 999

Having skeletons of cartilage, not bone, sharks and rays are known collectively as cartilaginous fishes. Shark evolutionary history extends back some 400 million years, while rays probably first appeared 200 million years ago. All feed on other animals and most are marine. Teeth are embedded in connective tissue and replaced throughout life; they usually have five, but sometimes six or seven, external gill slits on each side of the mouth; and all have internal fertilization. Together with skates (a type of ray) and chimaeras (a mainly deepwater group, including spookfishes, ghost sharks, and elephantfishes), sharks and rays today comprise about 1,000 species.



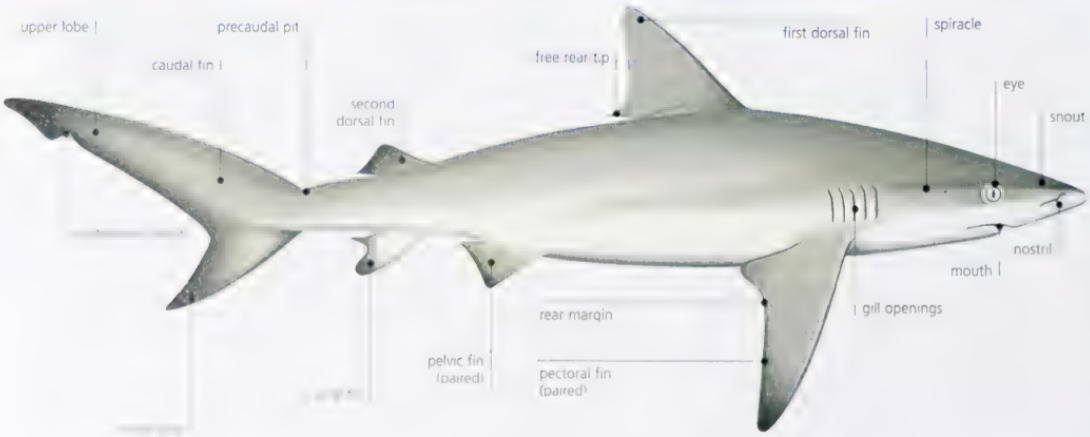
**Shark napping** Caribbean reef sharks (above) occur on reefs around islands in the Caribbean Sea. They are known for the way they rest motionlessly in caves and on the ocean bottom as if sleeping.

**Gentle giant** The largest living fish, the whale shark (left) is about 25 years old and 30 feet (9 m) long before it reaches sexual maturity. It roams the Indian, Pacific, and Atlantic oceans, mouth agape, filtering mainly plankton from surface waters

## ANCIENT FEATURES

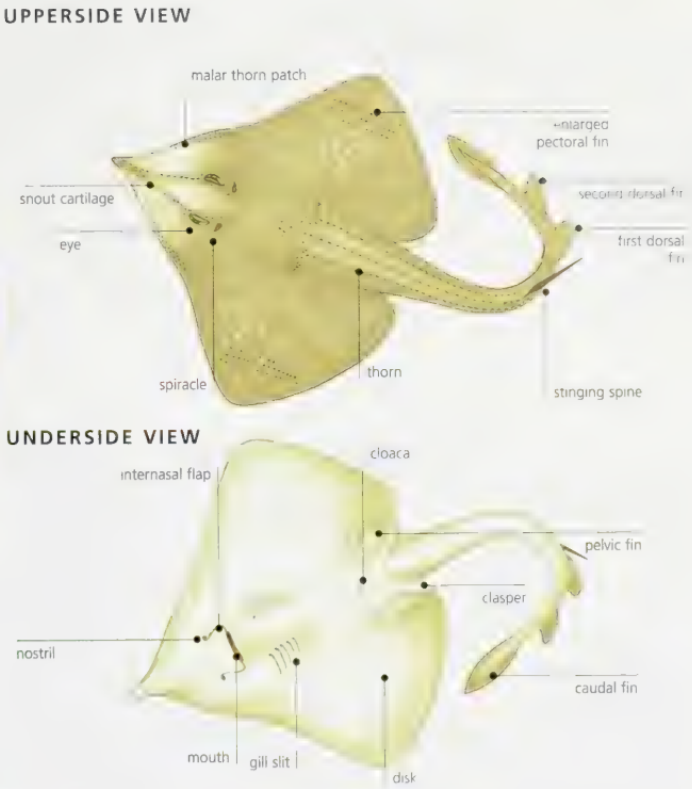
Unlike jawless fishes (which also have skeletons of cartilage), sharks, rays, and their close relatives have well-developed jaws, paired nostrils, and paired pectoral and pelvic fins. In addition to their cartilaginous skeletons, they differ from the bony fishes in having dermal denticles and teeth that are replaced throughout their lives or which are fused into continuously growing bony plates.

The class Chondrichthyes, to which the cartilaginous fishes belong, is usually divided into two subclasses. Elasmobranchii is a large group that includes the wide-ranging sharks, skates, and rays. The smaller Holocephali group contains the relatively "primitive" chimaeras. These bizarre-looking and mostly bottom-dwelling fishes differ from the elasmobranchs in having only a single gill cleft and four gills on each side of the head, mainly naked skin, teeth fused into plates, and the upper jaw fused to the skull.




**Shark anatomy** Basic shark attributes (left) have changed little since the group's early evolution. Body shape is designed for hydrodynamic efficiency and to suit a predatory lifestyle. Fins are thick, stiff, and usually lack spines. All sharks have paired pelvic and pectoral fins and between two and four unpaired anal, caudal, and dorsal fins. Gill openings are visible externally

***Excellent eyesight*** *Large eyes on short stalks provide this reef-dwelling ray with excellent vision to the front and sides*




## REPRODUCTION

All of the cartilaginous fishes have internal fertilization, and elaborate courtship rituals are believed to be widespread in the group. Males do not possess a penis but have claspers instead. These stiffened, fin-like rods, which extend parallel to the body from behind the pelvic fins, are inserted into the female's cloaca to guide sperm. Pup numbers range from 2 to 300 per pregnancy, depending on the species.

Most fishes adopt a strength-in-numbers approach to reproduction, dispersing sometimes millions of tiny eggs at a time so that at least some reach adulthood. In contrast, sharks and rays produce very few offspring but invest far more energy in their early development.

Some sharks and rays lay large yolky eggs that nourish embryos for months before hatching. In most sharks and rays, however, mothers retain young internally to give birth after a lengthy gestation. Either way, baby sharks and rays are born as miniature versions of their parents.

Parental devotion almost always ends with birth. In fact, the pups of many shark species probably separate quickly from their mothers to avoid ending up as prey.

**Feeding migrations** The blue-spotted ribbontail ray (*Taeniura lymma*) (above) moves in small groups on the rising tide to graze on invertebrates living on reefs. It returns with the falling tide to deeper water to hide under ledges and in caves.

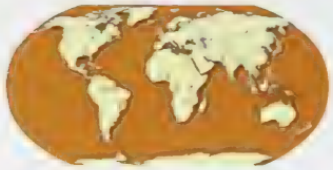
**Ray anatomy** Rays have flattened, disk-like bodies with eyes on the dorsal surface and a ventrally located mouth (left). They also have five or six pairs of gill slits located on the underside of the body, just behind the mouth. Rays take in water for respiration through large openings on the upper surface of the head called spiracles, as well as or instead of through the mouth. The long slender tail is often equipped with sharp spines to deter predators and is not used for swimming. Instead, rays propel themselves using their greatly enlarged wing-like pectoral fins. The caudal and dorsal fins are often reduced or lacking

**Powerful swimmers** Spotted eagle rays (*Aetobatus narinari*) are highly social fish that frequently frolic in groups near the ocean's surface. They move through the water with great strength and grace and have been reported to escape predators by leaping clear of the water

# SHARKS

**CLASS** Chondrichthyes
**SUBCLASS** Elasmobranchii
**ORDERS** 8
**FAMILIES** 31
**SPECIES** 415

Although less than 2 percent of living fish species are sharks, they are of crucial ecological importance in marine ecosystems because they are apex predators. As a result they occur at naturally low levels of abundance compared with most bony fishes. This, combined with low reproductive rates, makes sharks particularly vulnerable to overexploitation. Most only reach sexual maturity after 6 years, and some not until 18 years or more. They produce few young and embryos undergo long periods of development before birth. Chimaeras are related to the sharks but belong to the subclass Holocephali, which contains a single order with 3 families and 37 species.



**Widespread distribution** Sharks are found throughout the world's oceans, although very few species can tolerate polar waters. Most prefer shallow marine habitats but a small number of species, such as dogfish sharks, dwell at great depths

**"Mermaid purses"** Shark eggs are large and yolky. The purse-like outer layer is made of a tough keratinoid (horny) protein and can be up to 6¾ inches (17 cm) long. Each contains a single embryo that can take up to 15 months to mature.

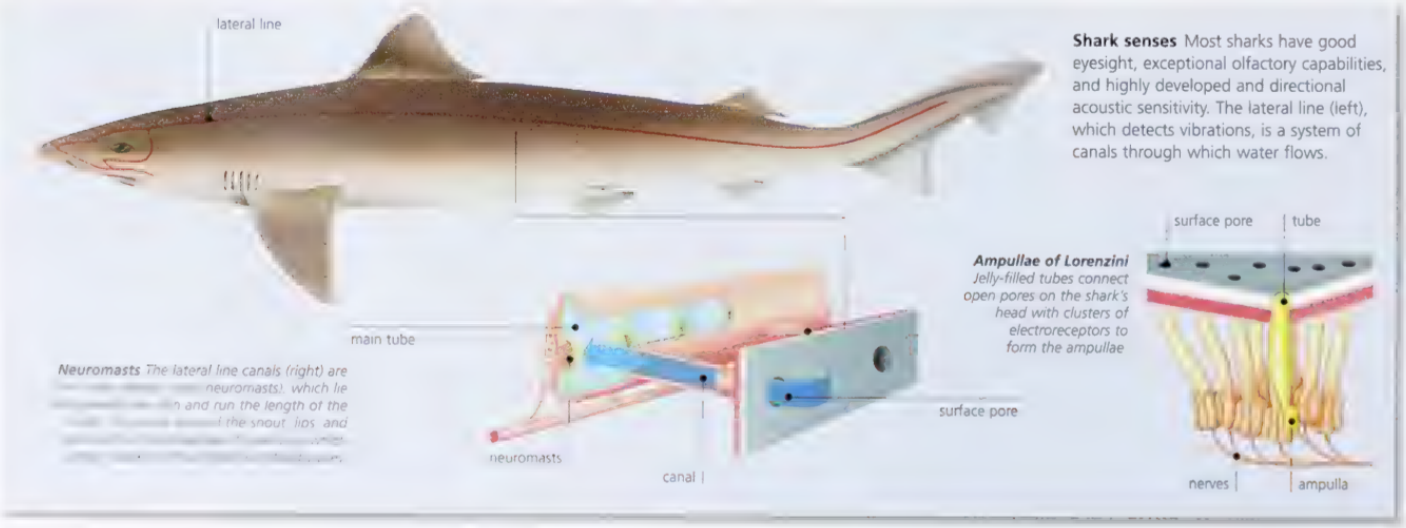
**Gatherings** Sharks don't school in the same highly coordinated way that bony fishes often do. But many species form aggregations. In the Sea of Cortez, large day-time groups of mainly juvenile female hammerheads form regularly in areas of high productivity (left). Reasons for this remain unclear

## PREDATORY LIVES

Because most sharks are highly active predators, they tend to be strong, agile swimmers, and some species make long migrations covering many hundreds of miles (km) in search of food. As they have slower metabolisms than most fishes, sharks do not need to feed as frequently and, despite their reputation as irrepressible killers, only hunt when necessary. Prey typically includes small fishes and invertebrates but the larger sharks also hunt sea turtles and marine mammals.

They have no internal swim bladder but other adaptations help to increase buoyancy and enhance their swimming capabilities. The cartilaginous skeleton, which is lighter than true bone, contributes. And large livers with high levels of oil also help keep many afloat. They do need, however, to keep swimming to avoid dropping to the ocean floor.

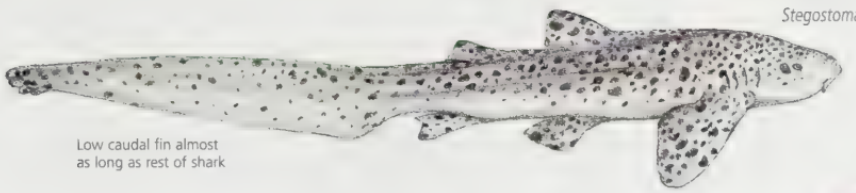
Sharks reduce water loss by retaining urea in their tissues.




**Shark senses** Most sharks have good eyesight, exceptional olfactory capabilities, and highly developed and directional acoustic sensitivity. The lateral line (left), which detects vibrations, is a system of canals through which water flows.

***Ampullae of Lorenzini*** *Jelly-filled tubes connect open pores on the shark's head with clusters of electroreceptors to form the ampullae*

***Neuromasts*** *The lateral line canals (right) are [illegible] neuromasts), which lie [illegible] and run the length of the [illegible] the snout, lips, and [illegible]*



Zebra shark
*Stegostoma fasciatum*

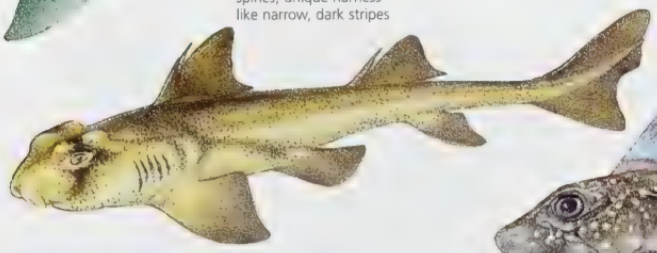
Low caudal fin almost as long as rest of shark

Rabbit fish
*Chimaera monstrosa*

Males have a clasper on their forehead, in addition to pelvic claspers

Broad, flat head and prominent ridges on body; lowermost expands into a keel in front of tail

Whale shark
*Rhincodon typus*



Shark has dorsal fins with spines; unique harness-like narrow, dark stripes

Port Jackson shark
*Heterodontus portusjacksoni*

Scaleless, with prominent lateral line and large spine at front of first dorsal fin

Spotted ratfish
*Hydrolagus colliei*

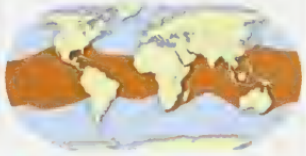
Moderately long barbels and minute spiracles

Nurse shark
*Ginglymostoma cirratum*

## FACT FILE

**Whale shark** Massive, filter-feeding whale sharks are believed to be highly migratory. They sometimes form loose aggregations of a hundred or more individuals but it is thought that most lead solitary lives

- Up to 59 ft (18 m)
- Up to 44,100 lb (20,000 kg)
- Ovoviviparous
- ♀♂ Male & female
- Vulnerable



Cosmopolitan: occur in all warm seas

## SHARK TAILS

Sharks have heterocercal tails: the vertebral columns extend well up into the upper lobe, which is always at least marginally bigger than the lower lobe. Tail shape suggests lifestyle. With a lower lobe almost as big as the upper, porbeagles are fast-swimming and capable of rapid acceleration. The marked tail asymmetry in the tiger shark indicates a slower swimmer.

nurse shark

tiger shark

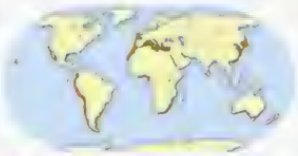
thresher shark

porbeagle

## FACT FILE

**Smooth hammerhead** This mostly temperate species feeds on bony fishes, small sharks and rays, crustaceans, and squid. Groups migrate to lower latitudes

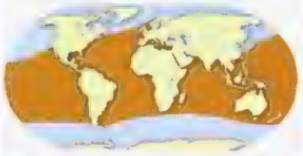
- Up to 16½ ft (5 m)
- Up to 880 lb (400 kg)
- Viviparous
- ♀♂ Male & female
- Near threatened



Widespread in temperate and tropical seas

**Blue shark** Courtship in the wide-ranging blue shark is so aggressive that, to cope with the nips and bites of mates, females have evolved skin more than twice as thick as that of the males.

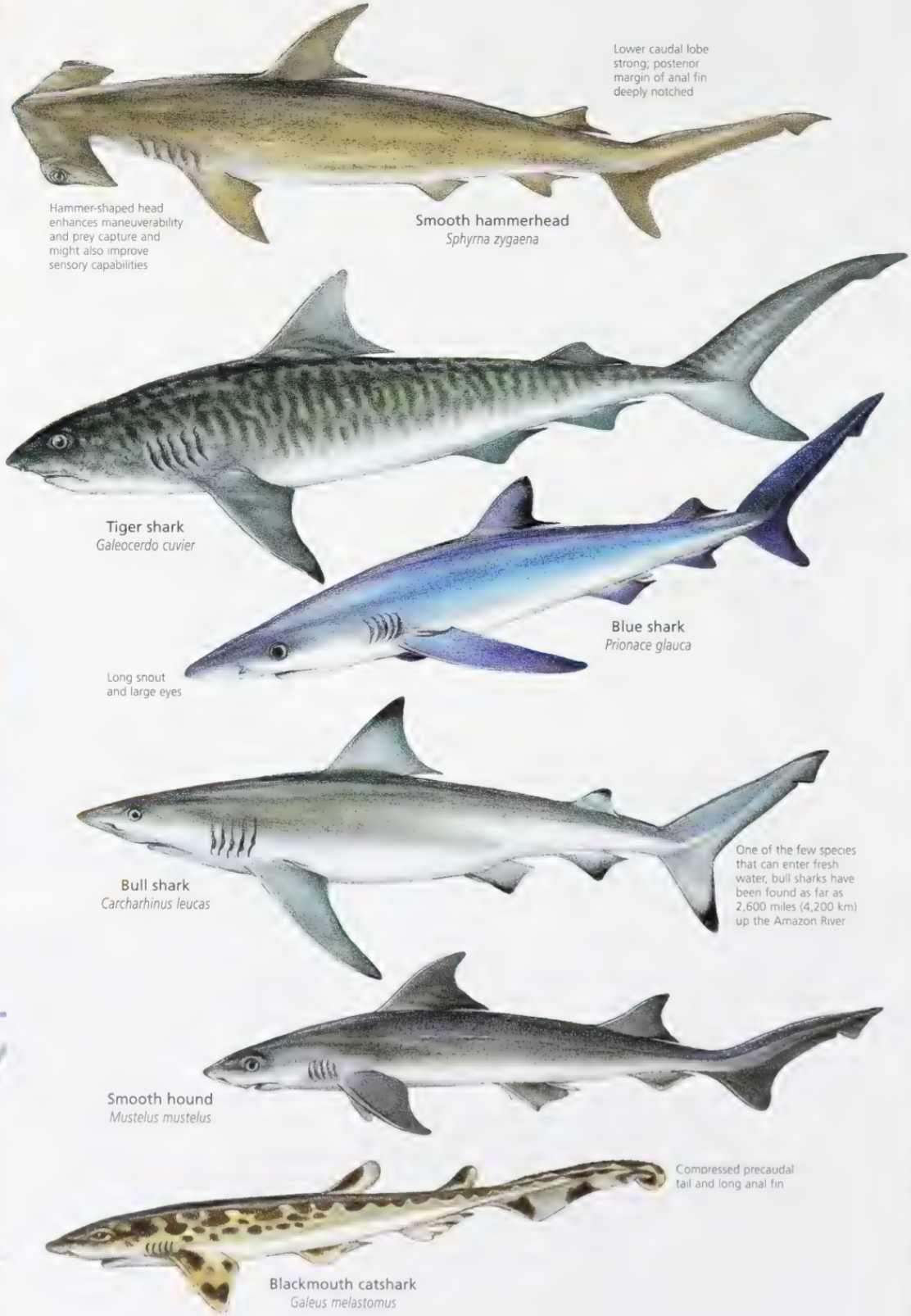
- Up 13 ft (4 m)
- Up to 452 lb (205 kg)
- Viviparous
- ♀♂ Male & female
- Near threatened



Widespread in temperate and tropical seas

## AGONISTIC DISPLAY

When threatened, grey reef sharks indicate their readiness to attack by raising the snout, dropping the pectoral fins, and holding the tail sideways as the back is arched and flexed. They swim like this in a figure-of-eight pattern with increasing intensity until they make either a rapid attack or retreat



Thresher shark
*Alopias vulpinus*

Thresher shark uses its long tail to round up, stun, and even kill fish

Sand tiger shark
*Carcharias taurus*

Basking shark
*Cetorhinus maximus*

Second-largest fish in the world; filter feeder

White shark
*Carcharodon carcharias*

Shortfin mako
*Isurus oxyrinchus*

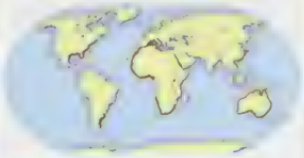
Porbeagle
*Lamna nasus*

Prefers water cooler than 65°F (18°C)

## FACT FILE

**Sand tiger shark** The embryos of sand tiger sharks cannibalize each other until only one in each uterus survives. As a result, these sharks can only ever produce two pups per pregnancy.

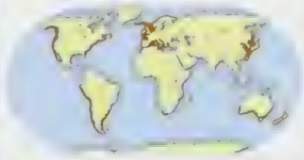
- Up to 10½ ft (3.2 m)
- Up to 348 lb (158 kg)
- Viviparous
- ♀♂ Male & female
- Vulnerable



Widespread in warm seas except E. Pacific

**Basking shark** These huge sharks filter tiny animals from surface waters and can process a body of water equivalent in size to an Olympic pool every hour.

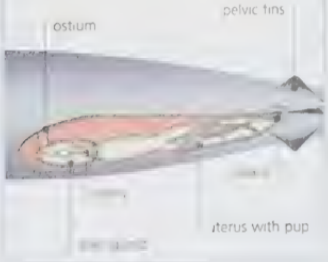
- Up to 32 ft (9.8 m)
- Up to 8,820 lb (4,000 kg)
- Ovoviviparous
- ♀♂ Male & female
- Vulnerable



Cosmopolitan in temperate and tropical seas

## PLACENTAL VIVIPARITY

Developing young in some sharks—including blue and hammerhead sharks—are nourished, like mammals, by maternal nutrients. Embryos hatch in the oviducts and live initially off egg sac yolk after which empty sacs develop into placentae that interweave with the uterine walls. Yolk stalks become "umbilical cords" extending from between the embryos' pectoral fins. Sharks with placental viviparity can produce up to a hundred offspring with every pregnancy, depending on the species.



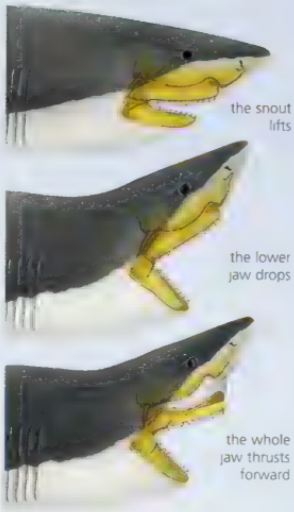
# THE BIG BITE

A daytime predator of fish, squid, stingrays, turtles, and marine mammals, the white shark is believed to have exceptional eyesight and to see in color. This huge carnivore has evolved to consume large meals infrequently and is thought to undertake long migrations to favored hunting grounds. The white shark is one of just 27 shark species that is known to have attacked either people or boats.

**Nocturnal hunter** The gray reef shark (*Carcharhinus amblyrhynchos*) has serrated triangular teeth and is a mostly night-time predator of fishes, mollusks, and crustaceans

**Menacing mouth** The mouth of the white shark can readily sever large pieces of flesh or chunks of blubber from large animals with its powerful jaws and massive bite. The multiple rows of razor-sharp, dagger-shaped teeth are serrated like steak knives and are constantly replaced

**Breaching behavior** White sharks around seal colonies off South Africa have been observed making sudden powerful and spectacular leaps, sometimes clear of the water, to snatch unsuspecting prey




**Protrusible jaws** As in other sharks, white shark jaws are connected to each other at their outer corners but hang loosely beneath the skull. The snout lifts as the bite begins, the lower jaw drops and, as the mouth opens, the whole jaw arrangement thrusts forward, providing extra reach

**Garbage guts** The tiger shark (*Galeocerdo cuvier*) (left) will attack and eat floating rubbish, such as tin cans

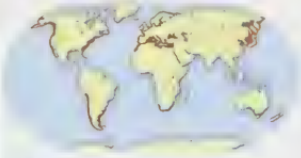
### SHARK TEETH

Teeth reveal much about shark prey preferences: white sharks have large, triangular-shaped teeth with serrated edges for tearing flesh; the flattened hind teeth of the hornshark crush hard-shelled invertebrates; blue shark teeth are finely serrated for catching fishes and squid; and the needle-like mako teeth are adept at grasping large, slippery prey

## FACT FILE

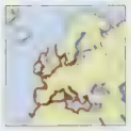
**Spiny dogfish** The spiny dogfish has one of the longest gestation periods of any cartilaginous fish—up to 24 months. With a life expectancy of about 70 years, it is one of the longest-lived sharks. Although a mostly deepwater species, it can form shallow-water coastal groups.

- Up to 5¼ ft (1.6 m)
- Up to 20 lb (9 kg)
- Ovoviviparous
- ♀♂ Male & female
- Near threatened



Cosmopolitan in temperate seas

**Angel shark** By day, this ambush predator lies buried in sediment with only its eyes uncovered. It bursts rapidly up to capture unsuspecting prey such as bony fishes, squid, skates, and crustaceans as they swim overhead



- Up to 8 ft (2.4 m)
- Up to 175 lb (80 kg)
- Ovoviviparous
- ♀♂ Male & female
- Vulnerable

E. North Atlantic & Mediterranean Sea

## FEEDING BEHAVIOR OF COOKIE-CUTTER SHARKS

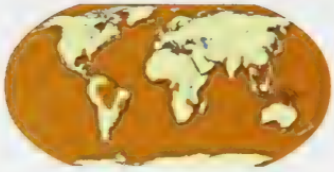
Cookie-cutters attach to prey with their suctorial lips, then spin around to carve deep round plugs of flesh using large triangular-shaped lower teeth. They remain attached with small hook-like upper teeth. It is thought that light-emitting organs on their undersides make them appear to be much smaller fishes when viewed from beneath. The illusion is revealed when would-be predators launch attacks and become prey instead. Cookie-cutter scars have been reported on large fishes, marine mammals, and even the rubber sonar domes of submarines.

Large teeth and very powerful jaws

# RAYS AND ALLIES

CLASS Chondrichthyes
SUBCLASS Elasmobranchii
ORDERS 3
FAMILIES 13
SPECIES 547

Body shape is the principal difference between these fishes and other cartilaginous fishes. Known as batoids, skates and rays are dorsoventrally flattened, an adaptation for a bottom-dwelling lifestyle. Their greatly enlarged pectoral fins extend from near the snout to the base of the tail. Together with the body, and often the head, they form the "disk," which can be triangular, round, or diamond-shaped. Most batoids take in water for gill ventilation through spiracles, openings located on the tops of their heads that are often mistaken for the eyes. Teeth are often plate-like and used for crushing prey, which ranges from bottom-dwelling invertebrates to pelagic fishes.

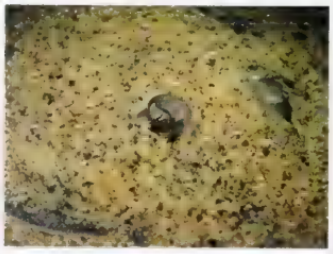


**Mostly benthic** Skates and rays are found in most benthic marine communities. A small number of ray families live in the open ocean and a few stingray and sawfish species survive in brackish estuaries and freshwater rivers and lakes, ranging from the tropics to polar waters. The guitarfishes, too—found in the temperate and tropical waters of the Atlantic, Pacific, and Indian oceans—are mostly marine

**Clever fishes** Rays are inquisitive, often sociable animals with complex behaviors. Although they are usually seen alone, many species will aggregate into loosely formed groups, particularly for the purposes of mating or migration.

**Typical skate**

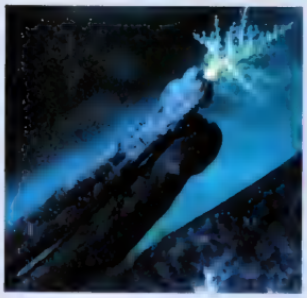
pectoral fin or wing



**Out of sight** Taking water through spiracles located just behind the eyes enables batoids, such as the thornback ray (above), to breathe while their mouths are buried. Most batoids have gill slits.

### DANGEROUS TAIL

The tail of the thorntail stingray (*Dasyatis thetidis*) can be twice as long as its body and makes a formidable weapon against would-be predators. Thick at its base, but whip-like toward the end, it is spiked with small sharp thorns and armed with one or two sharp, serrated, and venomous barbs. The venom is dangerous to humans.



## BATOID DIVERSITY

Almost half the living batoid species are skates, all of which are bottom-dwelling egg-layers with large flat disks and small tails. The dorsal surface usually bears "thorns" for defence against predators and these are also used by males to grip females during mating. Although some species can attain lengths over 8 feet (2.4 m), most are less than 3¼ feet (1 m). Most skates prefer shallow water but some are found to depths of 9,000 feet (2,750 m).

The rays are often categorized into four major groups: the electric rays, sawfishes, stingrays and their allies, and guitarfishes.

Sawfishes have distinctive flat elongated snouts with conspicuous "teeth" along their edges. These can account for as much as a third of the body length in adults. They are thrashed about in schools of fishes to stun and kill prey. Some of the seven known living species attain lengths of over 23 feet (7 m).

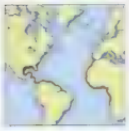
Electric rays stun prey using electric organs located behind the eyes. There are more than 40 species worldwide, all of which tend to be rather lethargic bottom dwellers.

Many of the 150-plus species of stingrays and their allies have slender tails armed with serrated spines and are powerful swimmers. They tend to be bottom dwellers but three families have adopted an open ocean lifestyle. The largest, the manta, attains widths in excess of 21 feet (6.4 m).

Guitarfishes comprise about 50 species and have well-developed tails and either a poorly developed or absent disk. They are all ovo-viviparous and tend to have more shark-like features than the other battoids, including well-developed tails bearing two dorsal fins.

## FACT FILE

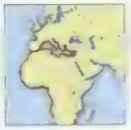
**Largetooth sawfish** This critically endangered ray uses the long, flattened, tooth-studded saw that extends from the front of its head, like other sawfishes, to slash at prey hidden in sediments or swimming in the water column as well as for defence against predators



- Up to 15 ft (4.5 m)
- Up to 1,000 lb (454 kg)
- Ovoviviparous
- ♀♂ Male & female
- Critically endangered

W. & E. Atlantic, Amazon River

**Marbled electric ray** A nocturnal feeder that uses shock tactics to paralyze its prey, the marbled electric ray produces electrical discharges of up to 200 volts from two large electric organs on its head



- Up to 23½ in (60 cm)
- Up to 6.5 lb (3 kg)
- Viviparous
- ♀♂ Male & female
- Uncommon

E. Atlantic & Mediterranean Sea

**Blue skate** The eggs of the blue skate, like those of other skate species, are encased in rectangular capsules of collagen, toughened with keratin and imbued with antibacterial sulphur

- Up to 9.4 ft (2.85 m)
- Up to 250 lb (113 kg)
- Oviparous
- ♀♂ Male & female
- Endangered

E. North Atlantic & W. Mediterranean Sea

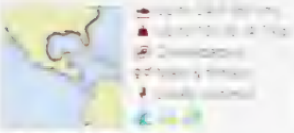
## MOVEMENT THROUGH WATER

Most skates and rays propel themselves through water using wave-like vertical undulations of their pectoral fins—almost like flapping birds. The electric rays and guitarfishes, however, swim more like sharks, using horizontal movements of their tails and caudal fins

***Graceful swimmers***
*As the pectorals flap*

## FACT FILE

**Atlantic stingray** [illegible]



[illegible]

**Common stingray** [illegible]

[illegible]

## STINGRAY TAIL

Stingrays are the largest fishes with venom. Many have tails equipped with at least one and often two, serrated barbs or spines. These are usually combined with sharp, backward-facing teeth and enclosed in a thin sheath of tissue that easily ruptures, releasing a cocktail of mucus (glue) with venom (activated when glands at the base of each spine). This sheath lubricates and reveals the spines when the spine is [illegible] or attacked.

***Fierce weapon*** *As well as* [illegible]

## CONSERVATION WATCH

**Vanishing sawfishes** All seven sawfish species (family Pristidae) are on the IUCN Red List: five are endangered and two are critically endangered. They are a particularly vulnerable bycatch in commercial coastal and estuarine net fisheries. Habitat destruction and pollution have contributed to their decline. They mature late, are long-lived, and have few pups, which means populations recover slowly.

Manta
*Manta birostris*

Cownose ray
*Rhinoptera bonasus*

Spotted eagle ray
*Aetobatus narinari*

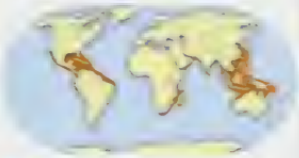
Devil fish
*Mobula mobular*

Bat ray
*Myliobatis californica*

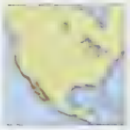
Common eagle ray
*Myliobatis aquila*

## FACT FILE

**Manta** [illegible]



**Bat ray** During mating, the male bat ray takes a firm grip on the pectoral fins of the female. This keeps the pair almost together in "embrace" as the male maneuvers around to insert a clasper into the female.



## FILTER FEEDING

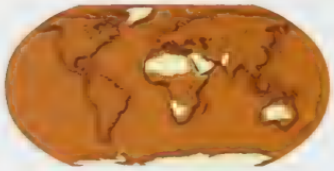
Feeding mantas are often seen swimming at leisure in surface waters. These vertical filter feeders collect the tiny animal plankton from the passing

**Feeding** with [illegible]

# BONY FISHES

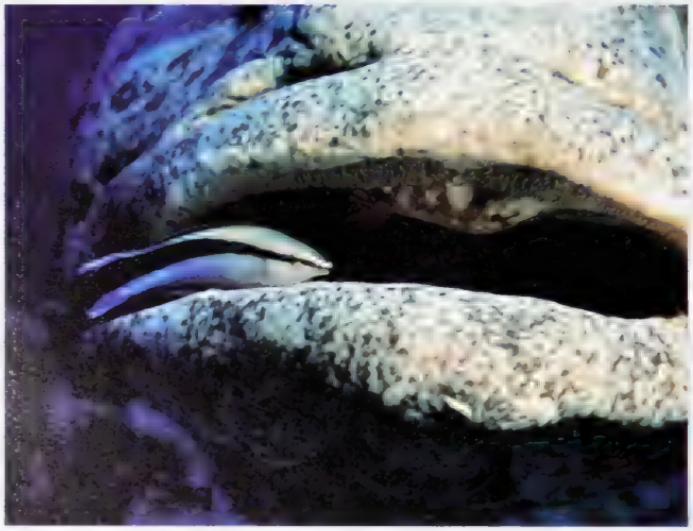
SUPERCLASS
OSTEICHTHYOMORPHA
CLASSES 2
ORDERS 48
FAMILIES 455
SPECIES 24 673

In terms of both species and total numbers, this is by far the most successful living vertebrate group. Bony fishes first appeared about 395 million years ago, the fossil record indicating that the earliest forms inhabited fresh water. There are two distinct evolutionary lineages. The lobe-finned fishes (the sarcopterygians) are now represented by only a small number of living species. They are critically important in evolutionary terms because their ancestors gave rise to the earliest tetrapods—four-limbed land vertebrates—which, in turn, ultimately led to all other vertebrates. The overwhelming majority of living bony fishes, however, are the ray-finned fishes—the actinopterygians.



**Successful radiation** The bony fishes are found in virtually every available marine, freshwater, and brackish habitat throughout the world, and occasionally even desiccated environments. Species diversity increases nearer to the tropics and decreases toward the poles. Diversity tends to be highest close to coastlines and lowest in the open ocean.

**Safety in numbers** [illegible]



**Symbiotic harmony** [illegible]

## EFFECTIVE EVOLUTION

Bony fishes are distinguished, as the name suggests, by a lightweight internal skeleton that is strengthened entirely or partially by true bone.

The fins of bony fishes are supported by more complex skeletal and muscle arrangements than those of cartilaginous fishes, giving bony fishes much finer control of swimming movements. As a result, many can move backward and even hover mid-water.

Maneuverability is also enhanced by the capacity to precisely and immediately adjust their buoyancy. This is achieved with a gas-filled sac known as a swim bladder. In some species, this is connected to the gullet and emptied and filled via the mouth, requiring fishes to gulp air at the water's surface. Mostly, however, there is no external connection and the swim bladder's content is controlled by the transfer of gases between adjacent blood vessels.

As they have a flap covering the gills (an operculum) and additional bony supports in the gill chamber known as branchiostegal rays, bony fishes can pump water over their gills and do not need to move forward to breathe.

About 90 percent of all bony fishes expel their reproductive cells from the body, making use of the watery environments in which they live for fertilization and the distribution of young.

Although cartilaginous fishes sometimes form aggregations, they don't school in the same highly coordinated way as many bony fishes, behavior made possible by a well-developed lateral line system and exceptional hearing and vision. Schools confuse predators by making lone targets difficult to select

**Fish lure** The heads of anglerfishes (below) are equipped with a bony rod complete with a fleshy "bait" at the tip to attract prey. This is often waved around to enhance the ruse but the strategy doesn't always work as planned. Anglerfishes have been found with missing lures, suggesting their prey sometimes escapes with the bait.

## SUCCESSFUL MOVEMENTS

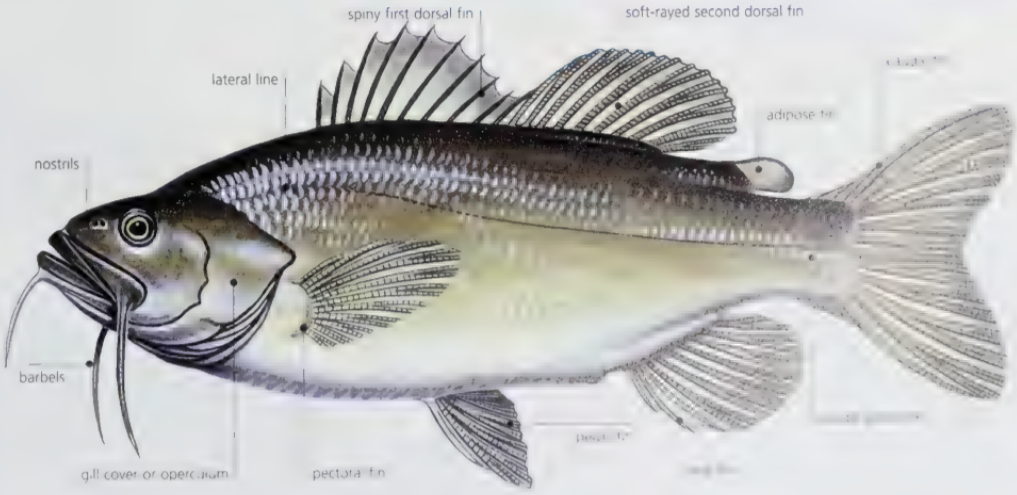
Migration has been another significant behavioral adaptation among bony fishes that has helped underpin the group's success. Mass, predictable movements are undertaken by many species to exploit changing food resources, avoid predators, or for the purposes of mating and spawning.

Such movements can be vertical, from deep to shallower waters and back, and measured in just meters. Horizontal migrations, however, can cover many hundreds, and even thousands, of miles (kilometers). When this involves migration from fresh water to ocean and back, and most of a species' life is spent at sea, it is termed anadromy. This is typical of the salmon family. The reverse—ocean to fresh water and back—is termed catadromy and is typical of freshwater eels.

Spawning migrations are common among the bony fishes because they allow adults and young to exploit different niches or even habitats.

**Deadly stalker** Venom glands at the base of the fin spines of red lionfish (*Pterois volitans*) (above) deliver a poison that is potentially fatal to humans. This highly aggressive and mostly solitary fish tends to hide by day and hunt by night, stalking prey such as small fishes and crustaceans, which it corners by stretching out and expanding its fan-like pectoral fins.

**Arduous journeys** Like most tuna species, the northern bluefin (*Thunnus thynnus*) is highly migratory. It forms large schools of like-sized fish to make seasonal movements thought to be influenced by spawning, water temperature, and prey aggregations. One study found that northern bluefins migrated across the Atlantic at an average of 40 miles (65 km) per day, covering 4,800 miles (7,700 km) in just 119 days.

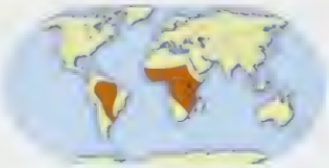



**Bony fish anatomy** The gills of nearly all adult bony fishes are covered by an operculum. Most species have thin, flexible scales covered by a thin mucus-secreting skin layer. Teeth are fixed to the upper jaw. The upper and lower lobes of the tail are usually symmetrical and the vertebral column stops before the fin. Most bony fishes have at least one dorsal fin, one anal fin, and paired pectoral fins. Except for a number of viviparous species, males do not have external organs to aid reproduction.

# LUNGFISHES AND ALLIES

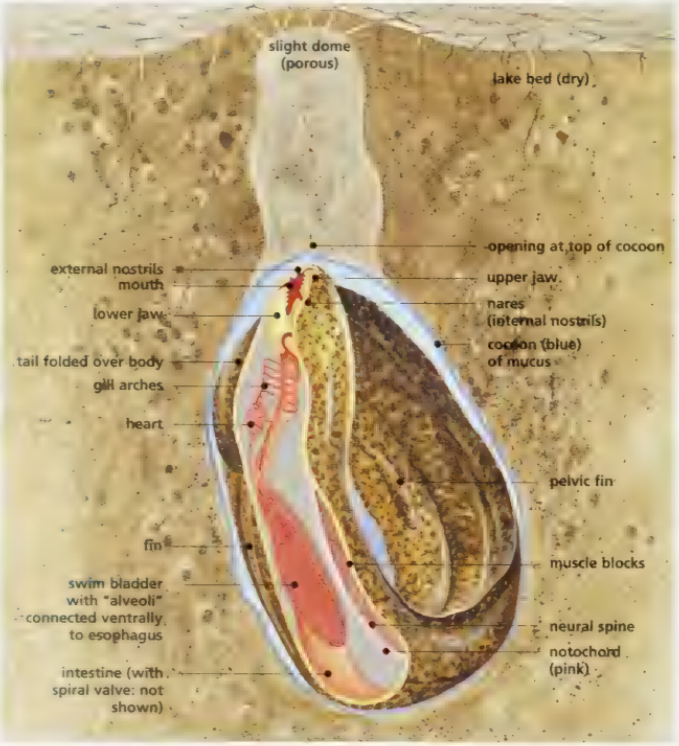
CLASS [illegible]
SUBCLASSES 2
ORDERS 3
FAMILIES 4
SPECIES [illegible]

Long-extinct ancestors of this relict group, known as the Sarcopterygii or "lobe-finned fishes," gave rise to the earliest land animals. Today, just nine lungfish and two coelacanth species survive. All have fleshy fins with skeletal structures and musculature more reminiscent of tetrapod limbs than they are of the fan-like fins of most other living fishes. In fact, 19th-century scientists mistakenly classified lungfishes as both reptiles and amphibians before realizing that they were fishes. Larval lungfishes breathe through gills but, in all but one species, adults rely on lungs to survive, allowing them to exist in waters with low oxygen levels. They occur in tropical freshwater rivers, lakes, and floodplains, while the gill-breathing coelacanths are exclusively marine.



**Restricted distribution** Lungfishes survive only in Africa, South America, and Australia. One of the two coelacanth species (*Latimeria chalumnae*) is known from a small number of specimens caught off coastlines in the Indian Ocean around the Comoros Islands. The other (*L. menadoensis*) was discovered off Sulawesi in Indonesian waters in 1999. These are the only two known sites that support living coelacanth populations.

**Surviving desiccation** The African lungfish [illegible] Africa's [illegible] during the dry season in a [illegible] burrow. Right, [illegible] breathe air through a tube that connects with the surface. It can exist in this condition for years.




## AIR-BREATHERS

African and American lungfishes have two lungs and thread-like paired pectoral and pelvic fins. Spawning occurs at the onset of the rainy season to aid survival of the gill-breathing larvae. Adults endure protracted dry spells by estivating in burrows, extracting oxygen from air via their lungs.

The Australian lungfish has a single lung and paddle-shaped fins. Although it can breathe air, it retains functional gills and cannot survive complete desiccation.

### CONSERVATION WATCH

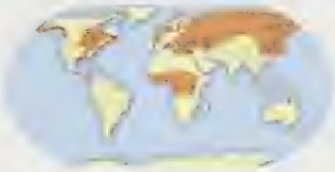
**Facing extinction** Listed on the IUCN Red List as critically endangered, the coelacanth *Latimeria chalumnae* is known mainly from the Indian Ocean's Comoros Islands, where the world's largest population of this fish is thought to comprise just several hundred adults. Growing to 6 feet (1.8 m) in length, it is late to mature and long-lived. Females have a long gestation period of 13 months and bear live young.

**Living fossils** Coelacanths were thought to have been extinct since the time of the dinosaurs, 65 million years ago, until one was caught in 1938 off the coast of Madagascar by some fishermen.

# BICHIRS AND ALLIES

| | |
|---|---|
| CLASS | Actinopterygii |
| SUBCLASS | Chondrostei |
| ORDERS | 2 |
| FAMILIES | 3 |
| SPECIES | 47 |

During the Permian period (285–245 million years ago) the direct ancestors of fishes such as the bichirs, reedfish, sturgeons, and paddlefishes—known collectively as chondostreans—were widespread and numerous both in species and total numbers. Today, these most primitive of the living ray-finned fishes have restricted distributions and are largely considered relics with archaic features. Most have rhombic-shaped scales hardened with a coating of an enamel-like substance called ganoine, not seen in modern species. Spiracles and intestinal spiral valves, characteristics more typical of cartilaginous fishes, are other common features. Most also have a single dorsal fin and a swim bladder, used for breathing air, connected to the gut.



**Relict distribution** Although fossil records reveal this group once occurred worldwide, its distribution is now restricted to Europe, Asia, Africa, and North America. One paddlefish species occurs in the eastern United States, the other in China. Fossils of the freshwater bichir and reedfish family (Polypteridae) have been uncovered in North Africa but it is now confined to tropical Africa and the Nile River system.

**Fish delicacy** Caviar (unfertilized sturgeon eggs) has become a symbol of opulence and indulgence. When the ripe females are stripped of their roe and released alive, it is a renewable resource. Too often, however, these fishes are killed for their roe.

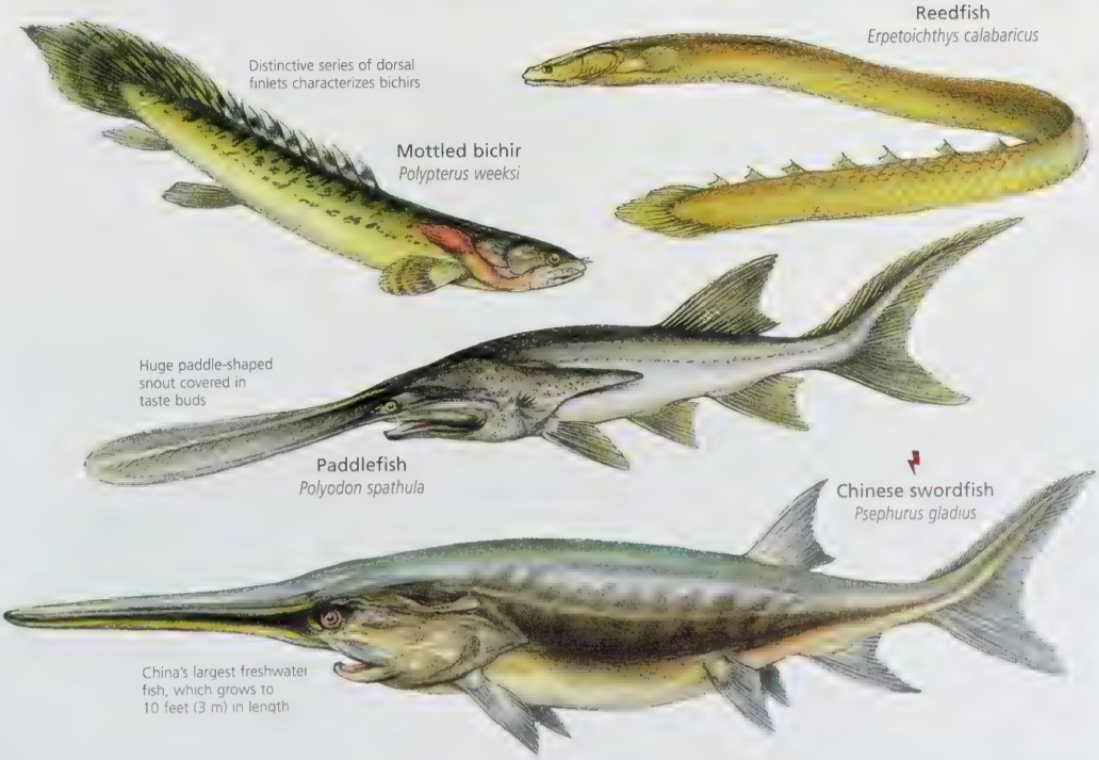
**Sensitive snouts** The elongated snouts of paddlefishes, which account for as much as half their adult length, have a sensory function and are richly endowed with electroreceptors. These fishes are largely freshwater and feed by filtering zooplankton from the water. Although once thought mistakenly to be sharks, their closest living relatives are sturgeons.

## STURGEON FEATURES

Sturgeons have been better studied than the other chondostreans, because of their high economic value. Found in both fresh and coastal marine waters, they are very large, long-lived fishes that take many years to reach sexual maturity. Females only spawn every few years.

Like the paddlefishes, sturgeons have several shark-like features, such as partly cartilaginous skeletons and heterocercal tails, where the vertebral column extends well into the tail's upper lobe.

They are unique among the living actinopterygians in having five rows of bony plates running along the body. They also have long flattened snouts and several tentacle-like barbels surrounding a ventrally located protractile mouth.




### CONSERVATION WATCH

**Sturgeon losses** Overharvesting of caviar, habitat degradation, and overfishing [illegible] sturgeon populations [illegible] late 20th century. Many species are included on the [illegible] including five that are classified as critically endangered. [illegible] efforts to [illegible] sturgeon [illegible] the [illegible] Threatened Species in Endangered Species Wild Fauna and Flora in Danger.

## FACT FILE

**White sturgeon** The largest of the freshwater fishes in North America, the white sturgeon grows to 20 feet (6 m) in length and attains weights of up to 1,500 pounds (680 kg). Sturgeons are flourishing, being bred and the species is thought to have a life expectancy of at least a century.

Up to 20 ft (6 m)
Up to 1,800 lb (820 kg)
Omnivorous
Both male & female
Very endangered

**Stellate sturgeon** This fish has all the characteristic sturgeon features. The upper and lower jaws are in the form of a tube, a hanging snout and a protrusive mouth with toothless mouth, and barbules. Having retractable protrusions smooth as cobblestones from the mouth. Behind the snout, the sturgeon's elongated body bulges in segments in search of crustacean as well, fishes and invertebrates.

Up to 7 ft (2.2 m)
Up to 440 lb (200 kg)
Omnivorous
Both male & female
Endangered

Among the fish, the Caspian sea sturgeon has

**Beluga** Often described as the "most, expensive fish in the world", the beluga is the most sought-after of the seven sturgeon species, because of both the quality and quantity of its roe. A 13 foot (4 m) female can yield 440 pounds (200 kg).

Up to 13 ft (4 m)
Up to 1,760 lb (800 kg)
Omnivorous
Both male & female
Endangered

Even in Asia a Caspian sea, Western sea

### STERLET

The sterlet (Acipenser ruthenus) is a dark coloured sturgeon and considering its size it is the smallest freshwater sturgeon feeding the Black and Caspian seas. It Europe, Old, some fishing, but other suggest it is a case of "accidental extinction", being at great risk, very, fishing, fishing gathering sturgeon caviar, sturgeon.

# PRIMITIVE NEOPTERYGII

CLASS Actinopterygii
SUBCLASS Neopterygii
ORDERS 2
FAMILIES 2
SPECIES 8

The Neopterygii are the second of the two living ray-finned fish groups. They arose from primitive fishes—probably early chondostreans—some 250 million years ago and, compared with their predecessors, had more mobile mouth parts, more symmetrical compact tails, and a simpler fin structure. Such advances enhanced feeding and swimming capabilities and the group ultimately gave rise to the extraordinarily successful teleosts, which comprise the majority of living fish species. Features of the earliest Neopterygii can still be seen today in a few surviving primitive representatives of the group: the bowfin and the seven species of gars, all of which are agile and voracious predators.

**Northern Hemisphere inhabitants** The bowfin is mostly restricted to still bodies of fresh water in temperate eastern North America. Five gar species are found in eastern North America. The remaining two species occur in Central America.

**Rapacious carnivore** The longnose gar (above) is, like all other living gars, an aggressive ambush predator of other fishes and crustaceans. It is capable of rapid acceleration and armed with long rows of sharp teeth in an elongated "beak."

## ANCIENT FISHES

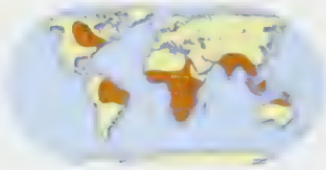
Gars and the bowfin have elongated body shapes, abbreviated shark-like heterocercal tails, and numerous sharp teeth. They inhabit mostly still-water swamps and backwaters where they can survive low levels of dissolved oxygen by using lung-like gas bladders to breathe air. Gars have primitive, interlocking ganoid scales, while the bowfin has cycloid scales, the type common in more modern fishes.

**Bayou dweller** Like other semionotiforms the alligator gar (*Atractosteus spatula*) (above) is an aggressive carnivore with lightning reflexes that prefers slow-moving, poorly oxygenated, swampy backwaters. Growing to almost 10 feet (3 m) in length, it is the largest of the seven gar species.

# BONYTONGUES AND ALLIES

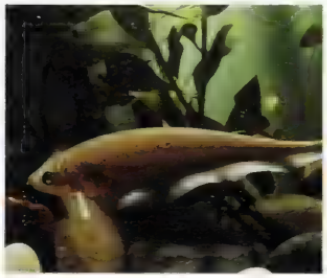
CLASS Actinopterygii
SUBDIVISION Osteoglossomorpha
ORDER Osteoglossiformes
FAMILIES 6
SPECIES 221

These fishes, the osteoglossomorphs, are considered the most primitive of the modern teleosts. The term bonytongue describes a trait shared by all members of the group: well-developed, tooth-like tongue bones that bite against teeth on the roof of the mouth. Beyond this unifying trait—and the fact that all are exclusively freshwater, even though the fossil record indicates that some past forms may have endured brackish water—these fishes exhibit an extraordinary diversity of form and behaviors. They are found on all continents except Europe and Antarctica, with most species occurring in Africa and just one family containing two species in North America.



**Tropical endemics** True bonytongues occur in South America, Africa, Australia, Malaysia, Borneo, Sumatra, Thailand, and New Guinea. Featherbacks are restricted to Asia and Africa. All elephantfish species are found only in Africa.

**Odd-shaped head** The arawana (right) has a distinctive appearance. It has two forward-pointing sensory barbels on the chin and a large trap-like mouth in which the lower jaw edge opens almost vertically.



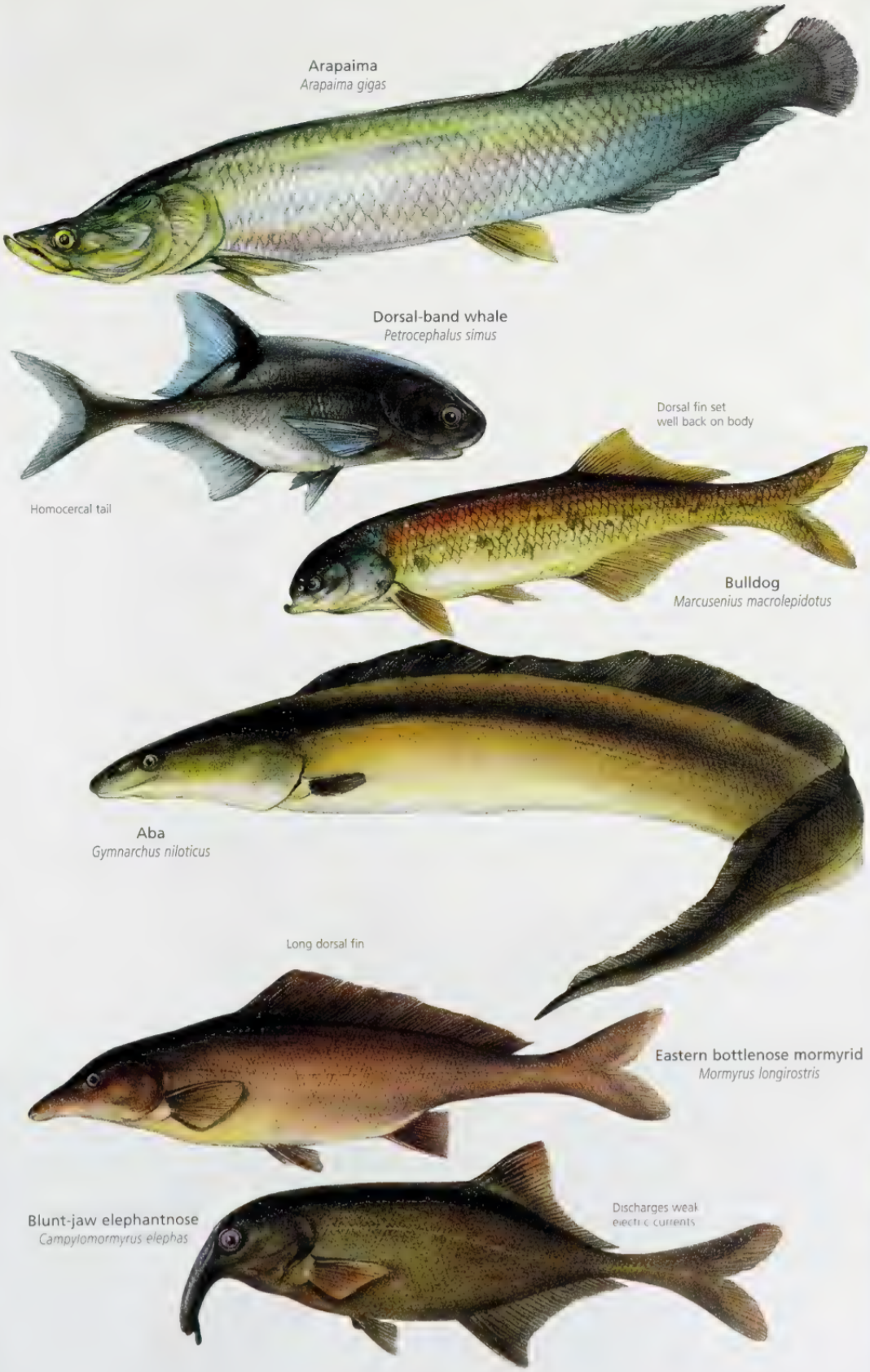
**Skillful swimmer** With rippling movements of its ventral anal fin, the African knifefish (*Xenomystus nigri*) above) can swim backward with as much ease as forward.

## FRESHWATER CURIOSITIES

There are three main groups in the osteoglossomorph subdivision. True bonytongues range from a small butterfly fish that seemingly glides in air using its well-developed pectoral fins, to the arapaima, one of the largest freshwater fishes.

Featherbacks have almost no tail fin but their anal fin runs two-thirds of their body length.

The elephantfishes, the third main group, includes species with elongated snouts that look like elephant trunks. Anal fin shape differs between the sexes in these bizarre-looking fishes. It is thought these fins are brought together in spawning pairs to form a cup into which eggs and sperm are ejected and mixed.




## FACT FILE

**Arapaima** Also known as the pirarucu, this giant species is one of the largest freshwater fishes. Parental care by both males and females is well developed and begins with the making of nests for up to 50,000 eggs at a time. Once the eggs hatch, the parents guard the developing embryos and then protect the free-swimming fry

- Up to 15 ft (4.5 m)
- Up to 440 lb (200 kg)
- Oviparous
- ♀♂ Male & female
- Data deficient

N. South America

**Aba** This species is in the same superfamily as the elephantfishes, but differs from all other members of that group in that it has no caudal, anal, or pelvic fins. It does, however, have a very long dorsal fin that runs much of its body length and can be over 5 feet (1.5 m)

- Up to 5½ ft (1.7 m)
- Up to 40 lb (18 kg)
- Oviparous, guarders
- ♀♂ Male & female
- Common

N. & N.W. Central Africa

## BIG BRAINS

enlarged "chin" used to probe muddy substrates for food

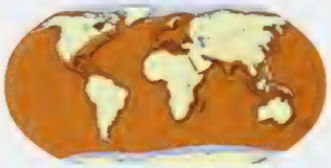
Elephantfishes have a very large brain, proportionately as big as a human brain when body sizes are compared, and are said to have strong capabilities for learning. They have a particularly well-developed cerebellum. This processes the sensory information they gather by electroreception, their most important sense. They can detect and produce weak electric currents, and can create an electrical field around the body, which they use in murky river waters and for night [illegible]

## CONSERVATION WATCH

Of the 221 species [illegible] in the Osteoglossiformes [illegible] bony tongues and their allies), 4 are included on the IUCN Red List, as follows

1. [illegible]
2. [illegible]
1. [illegible]

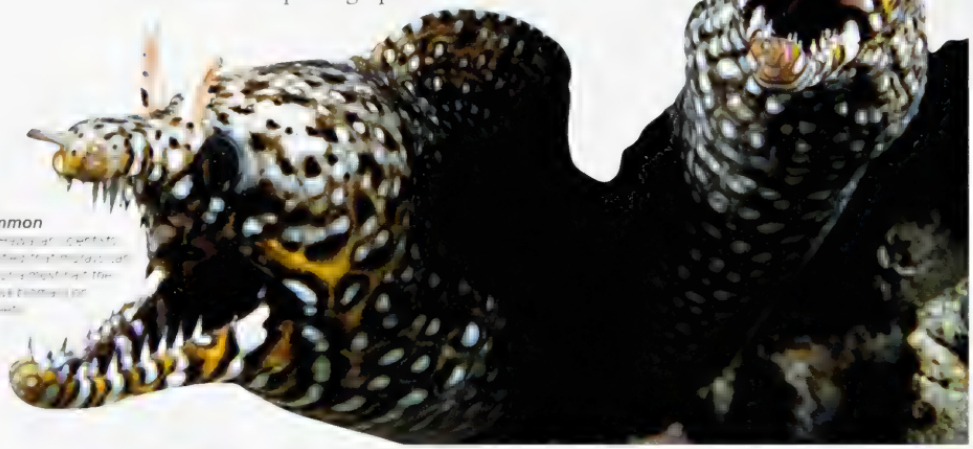
# EELS AND ALLIES



**CLASS** Actinopterygii
**SUBDIVISION** Elopomorpha
**ORDERS** 5
**FAMILIES** 24
**SPECIES** 911

Many of the more than 900 species grouped together among these fishes, the elopomorphs, appear at first to have little to do with the elongated snake-like creatures most people know as eels. All, however, are linked because they invariably begin life as leptocephalus larvae. These translucent ribbon-shaped organisms drift in ocean currents for up to 3 years before metamorphosing into juvenile versions of their adult forms. This diverse assemblage of mainly marine and estuarine species includes three major groups: "true eels," such as moray, conger, and freshwater eels; the tarpons, ladyfishes, bonefishes, halosaurs, and spiny eels; and the bizarre deep-sea gulper eels.

**Widespread distribution** Most true eels are found in tropical and subtropical seas and oceans, although members of the family Anguillidae spend most of their lives in temperate fresh water. Tarpons and their closest relatives occur mainly in warm coastal and estuarine waters. Spiny eels are found throughout the world's oceans down to depths of 16,000 feet (4,900 m). All four families of deep-sea gulper eels also occur worldwide in deep ocean waters.



***Cryptic but common***

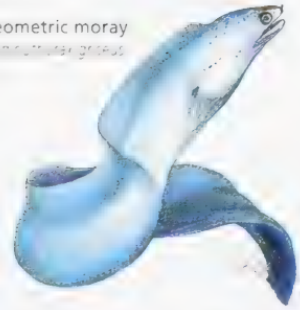
**Fierce faces** Many morays, such as the dragon moray (*Enchelycore pardalis*) (above), have wide jaws filled with large sharp teeth. This species also has unusually prominent nose-tubes. Bold color patterns are also common among the morays; these help to camouflage them on the tropical reefs where they live. There are more than 200 species of this largely nocturnal family of carnivores. They have relatively small eyes and poor vision and locate prey using their keen sense of smell.

## VARIED FORMS

With more than 700 species, the true eels are by far the largest group of elopomorphs. These have an elongated shape and almost all lack pelvic and pectoral fins. This streamlined body design suits a burrowing lifestyle and allows ease of movement into and out of holes around coral reefs.

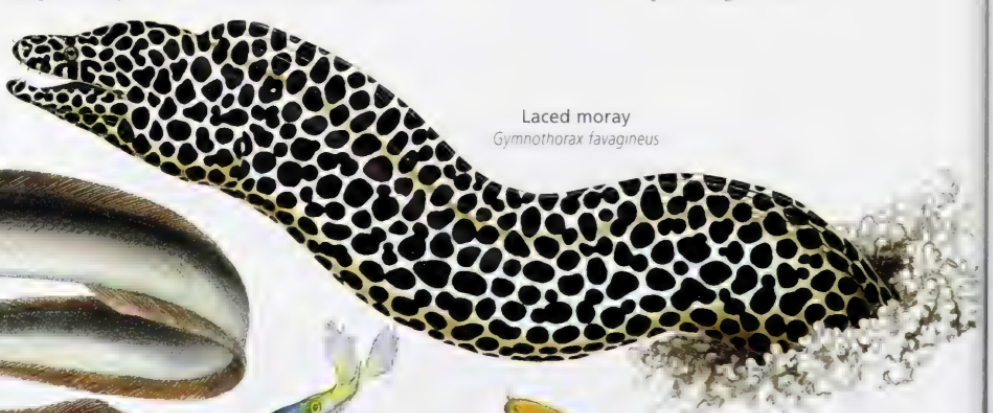
Adult tarpons, bonefishes, and ladyfishes have large metallic scales, forked tails, and a typical fish shape. The former two groups are highly regarded as sportfish.

The spiny eels have deep-sea habits, are long, scaled, and feed on slow-moving, bottom-dwelling invertebrates. Deep-sea gulper eels have elongate, scaleless bodies. Enormous mouths and highly distensible stomachs take advantage of infrequent large meals.



Geometric moray
*Gymnothorax gracilicauda*

European eel
*Anguilla anguilla*



Laced moray
*Gymnothorax favagineus*

Dragon moray
*Enchelycore pardalis*

Ribbon moray
*Rhinomuraena quaesita*

Dwarf moray
*Gymnothorax melatremus*

Tarpon
*Megalops atlanticus*

Pectoral and pelvic fins with axillary scales

Oxeye
*Megalops cyprinoides*

Lower jaw projects beyond snout

Ladyfish
*Elops saurus*

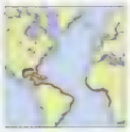
Bonefish
*Albula vulpes*

Blunt snout extends beyond inferior mouth

Threadfin bonefish
*Albula nemoptera*

## FACT FILE

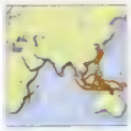
**Tarpon** Frequently the subject of sport-fishing legend, the Atlantic tarpon is sometimes called the "greatest gamefish in the world." They are hard to hook and land and will fight fiercely for many hours. During the struggle, they can leap explosively from the water.



Up to 8 ft (2.4 m)
Up to 350 lb (159 kg)
Oviparous
♀♂ Male & female
Common

Caribbean Sea, W. & E. Atlantic

**Oxeye** Like its close relative the tarpon, the oxeye is able to breathe atmospheric air in oxygen-poor environments and is often seen gulping air at the water's surface. These fishes are, however, far less tolerant of low temperatures and large kills can occur when waters suddenly become colder.

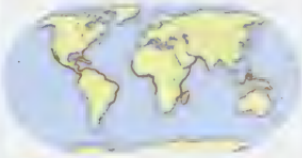


Up to 5 ft (1.5 m)
Up to 40 lb (18 kg)
Oviparous
♀♂ Male & female
Common

Indo-West Pacific

**Bonefish** A mainly coastal species that frequents river mouths and intertidal areas such as mangrove forests, the bonefish often occurs in highly coordinated schools of up to 100 individuals. They have a slender, typically torpedo-shaped body and a protruding conical snout that they use to dig in substrates for prey, mostly invertebrate.

Up to 3 ft (0.9 m)
Up to 22 lb (10 kg)
Oviparous
♀♂ Male & female
Common

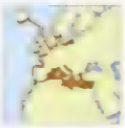


Worldwide in warm seas

## TOOTHED TURKEY

## FACT FILE

**European conger**



Oviparous, semelparous
♂♀ Male & female

**Pelican eel**

## EEL GARDENS

European conger
*Conger conger*

Serpent eel
*Ophichthus remiger*

Swallower
*Saccopharynx ampullaceus*

Spotted garden eel
*Heteroconger hassi*

Bean's sawtoothed eel
*Serrivomer beani*

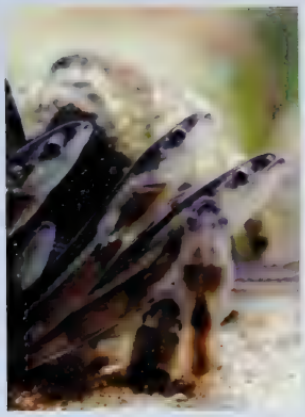
Pelican eel

Long tapering tail and enormous

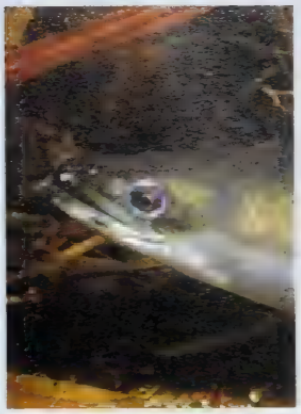
Snubnosed eel

# THE MYSTERIOUS LIVES OF FRESHWATER EELS

It was not until late in the 19th century that scientists began uncovering the truth about the life-cycles of the European eel (*Anguilla anguilla*) and its relative the American eel (*Anguilla rostrata*). Both species, it is now known, spawn in the Sargasso Sea, but precisely where remains a mystery. Their lives take decades and up to 7,000 miles (11,250 km) to complete. European eels head east, their American cousins west, both spending most of their lives in fresh water before returning to the Sargasso Sea to spawn once and die.



**Small beginnings** European eels are just 2–4 inches (5–10 cm) long when, after several years of oceanic drifting, they finally reach the estuaries that will take them to their freshwater adult habitats.



**Silver fishes** Adult European eels occupy freshwater feeding the North Atlantic Ocean and Baltic and Mediterranean seas. Females mature between 9 and 20 years; males between 6 and 12 years.

**Parallel lives** Adult European eels dwell in fresh water throughout Europe and parts of northern Africa. Their life history, below, mirrors that of the American species, in which adults occupy fresh water along North America's east coast. Research has shown that both species have suffered massive declines since the 1970s. Some investigations indicate adult European eel numbers may have fallen by 90 percent or more as a result of overfishing, pollution, disease, and habitat destruction.

***1. The journey starts***
*Like American eels, European eels spawn in the salty waters of the western Atlantic's Sargasso Sea, somewhere off the Bermudan coast. Leaf-like larvae, known as leptocephali, drift northeast on Gulf Stream currents for up to 3 years*

***2. See-through change***
[illegible]

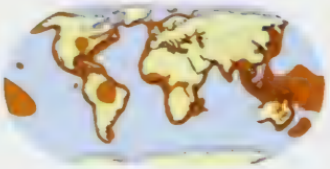
***4. Mature migration***
*Adult eels make their way downriver to the Atlantic Ocean to return to their birth-place, their sex cells maturing along the way. They [illegible] eat during the journey*

***3. Long lives*** [illegible]

# SARDINES AND ALLIES

DIVISION Teleostei
SUBDIVISION Clupeomorpha
ORDER Clupeiformes
FAMILIES 5
SPECIES 378

Known as the clupeoids, this group of 378 species comprises some of the world's most commercially important fishes, including herrings, sardines, anchovies, shads, and pilchards. Most are marine filter feeders of zooplankton that form large schools and lead pelagic lifestyles, although their distributions tend to be more coastal than open water. Spawning is frequently in near-shore surface waters and usually seasonal. Females mostly produce large numbers of small eggs which develop into larvae that can drift in surface currents for many months before metamorphosing into juveniles. Some species undertake extraordinary migrations as adults, covering thousands of miles (kilometres) and several years.



**Coastal preferences** The clupeoids are largely a Northern Hemisphere group. The adults of most species feed along the coasts of tropical and temperate seas, but more than 70 species inhabit freshwater rivers and lakes. Very few species occur far from shore in the open ocean and none are found in polar seas or at oceanic depths. Seasonal migrations to spawning grounds are common in the group.

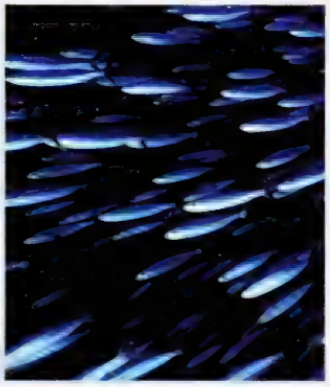
**Staying in school** The gill rakers of all clupeoids [illegible] are [illegible] known as an adaptation [illegible] to prevent their ability to detect [illegible] frequently results such as these produced by feeding tail fins, anything and [illegible] Large and brought [illegible] "[illegible]" are thought to [illegible] [illegible] and [illegible] at the [illegible] at night.

## BOOM-BUST POPULATIONS

Renowned for natural boom-bust population cycles, clupeoids suffer from extremely high mortality rates—frequently up to 99 percent—partly because they fall victim to a wide range of predators at all stages of their life cycle. They are also very vulnerable as adults to variations in food availability, a result of increasingly fluctuating environmental conditions.

Most species, however, have very high reproductive rates and reach sexual maturity at early ages (rarely later than 3 years of age). As a consequence, populations tend to bounce back quickly when good conditions prevail.

The clupeoid group contributes enormously to the total biomass of the world's aquatic environments and is a crucial lower link in many aquatic food chains.



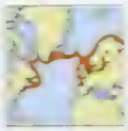
**Archetypal fish** Clupeoids, such as these herrings, are what most people visualize when they think of fishes. Small—most attaining weights less than 10 ounces (300 g)—streamlined, and silvering with wide lower grades and brown tips.

## FACT FILE

**American shad** Adult American shad leave most of their time in coastal marine and brackish waters but migrate without feeding to their spawning streams and there in eastern North America to spawn, each female releasing up to 400,000 eggs during one evening. This species is the largest of the shads and is noteworthy as the only one feeding, as the juvenile young would

North America

**Atlantic herring** Sometimes listed in the Guinness Book of World Records as the planet's most numerous fish species, the Atlantic herring has been observed running in 17 mile (27 km)-long schools containing millions of individuals. It is also fondness of this species for undertake daily vertical migrations. During daylight hours, they usually dive to the ocean floor 65 miles may live to keep, mostly on zooplankton.



North Atlantic

**Anchoveta** Perhaps the most commercially exploited fish in human history, the anchoveta has since taken at an annual rate of over 17 million tons (15 million tonnes). The various stream-out population pockets of the species appear to be exterminated periodically by overfishing.

SE South American coast

## CONSERVATION WATCH

**Shad shortages** The 19 species on the IUCN Red List include the endangered Kakum shad (Alosa alabamae) and the Kakum shad (Tenualosa macrura). The former is [illegible] species has been adversely affected by dam constructions that have impeded access to spawning areas, thus the disappearance of large numbers [illegible]

# CATFISHES AND ALLIES

**CLASS** Actinopterygii
**SUPERORDER** Ostariophysi
**ORDERS** 5
**FAMILIES** 62
**SPECIES** 7,023

These fishes, the ostariophysans, dominate the world's freshwater habitats. They form a massive group of over 7,000 species united by two key characteristics. A unique set of bones, the Weberian apparatus, connects the gas bladder and inner ear in an arrangement that enhances hearing. The second trait is an alarm response involving the release of distress chemicals from special skin cells. Many ostariophysans not only produce these substances but can also perceive and respond to them by fleeing. Some species that eat other ostariophysans, however, are not capable of the latter as most of their prey produce these alarm chemicals and reacting would thus inhibit feeding.

**Freshwater dominance** Most characins are tropical. Cyprinids are naturally found in North America and Africa, but most are found in Eurasia. Catfishes are found on all continents and the electric knifefishes are restricted to Central and South America. Many ostariophysans, however, are now found well beyond their original range, partly as a result of the aquarium trade.

**Sensing** The Indo-Pacific's striped eel-catfish is one of few primarily marine catfish species but the barbels around the mouth, which function as taste and touch receptors, are typical of catfishes. All species have at least one pair known as the maxillary barbels.

## ENORMOUS DIVERSITY

The most primitive ostariophysans are a tropical group with incomplete Weberian apparatus. The milk fish, an important protein source for people in Southeast Asia, is in this group.

The largest ostariophysan group, the cyprinids, includes the carps, minnows, and many of the world's most popular aquarium fishes, from goldfish to rasboras. These lack jaw teeth but grind food between a pharyngeal tooth-bearing bone and a hard keratinized pad at the base of the skull. This arrangement has been modified repeatedly to provide many different feeding strategies.

The mostly South American characins include species as diverse and well known as the piranhas and the aquarium favorites, the tetras.

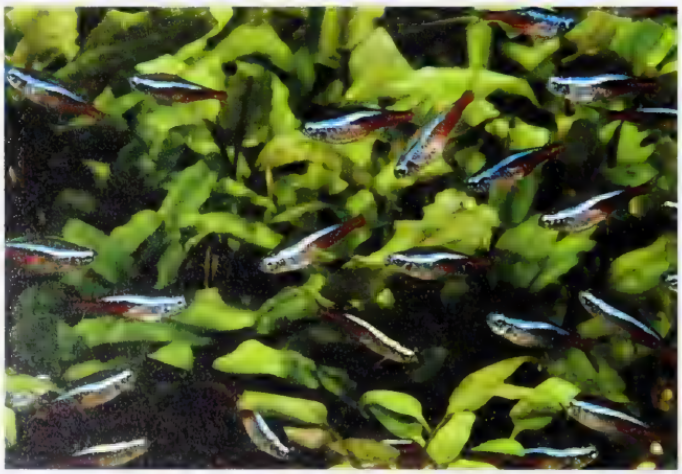
There are well over 2,000 catfish species, all readily recognized by tentacle-like barbels around the mouth. All are substrate feeders.

The electric knifefishes make up a small, specialized, and poorly studied group that includes the legendary electric eel.

### CONSERVATION WATCH

**Barely there** Once presumed extinct, the smoky madtom (*Noturus baileyi*) was rediscovered in a Tennessee stream in the eastern United States in 1980. Fewer than 1,000 adults of this tiny catfish, which grows to 2¾ inches (6 cm), survive.

In Southern Africa's Twee River and tributaries, the Twee redfin (*Barbus erubescens*) leads a similarly precarious existence, facing threats such as agricultural pollution and excessive water extraction. Intro- [illegible] fish, have taken a toll. There are among 49 critically endangered ostariophysans worldwide. A further 41 are endangered and 19 have already been extinct.



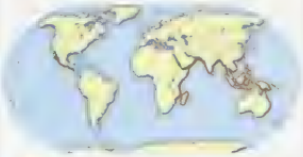
**Efficient feeders** In some but not all piranha species, short powerful jaws and sharp, interlocking teeth (above) enable flesh removal from prey in clean bites.

**Popular fish** Originally from the upper reaches of the Amazon River, neon tetras (left) have become a mainstay of the aquarium trade worldwide.

## FACT FILE

**Milk fish** Larval milkfish develop in brackish coastal wetlands and do occasionally enter fresh water but return to the sea to breed. This species is an important protein source for human populations throughout the Indo-Pacific, where it is sometimes farmed in ponds.

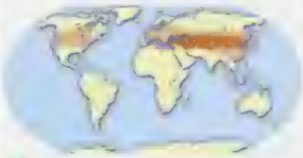
- Up to 6 ft (1.8 m)
- Up to 30 lb (14.5 kg)
- Oviparous
- ♀♂ Male & female
- Common



E. Africa, S.E. Asia, Oceania & E. Pacific

**Common carp** Originally native to parts of Europe and Asia, the common carp has been introduced throughout the world. It is a highly adaptable species with an omnivorous diet and in many places outside its original range is now considered a pest because it often outcompetes local native species.

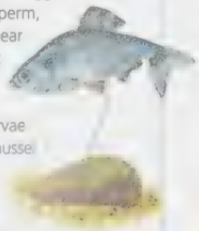
- Up to 4 ft (1.2 m)
- Up to 82 lb (37 kg)
- Oviparous
- ♀♂ Male & female
- Data deficient for wild carp



E. Europe to China; introd. worldwide
Introduced range

## BITTERLING

To breed, the female bitterling develops a long ovipositor down which she passes eggs into the gill chamber of a freshwater mussel. Eggs are fertilized when sperm, released by a male near the bivalve's inhalant aperture, is drawn in and mixes with the eggs. Bitterling larvae develop inside the mussel for up to a month



***Fish pregnancy tests***
*Female bitterlings were once used in [illegible] in women. Urine carrying traces of pregnancy hormones encourages ovipositor development when injected into these fish*

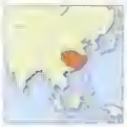
## FACT FILE

**Spanner barb** Many of the barbs are popular within the aquarium trade although the spanner barb tends to grow a little too large to be a very highly sought-after species

Up to 7 in (18 cm)
Up to 8 oz (225 g)
Oviparous
♀♂ Male & female
Common

Malay Peninsula to Borneo

**Chinese sucker** Native to the Yangtze River basin, this species' common name stems from its thickened lips, which are used to suck up food such as invertebrates and algae from sediments and around river rocks and plants. In some specimens, the dorsal fin can be almost as tall as the body is long



Up to 23½ in (60 cm)
Up to 8 lb (3.6 kg)
Oviparous
♀♂ Male & female
Locally common

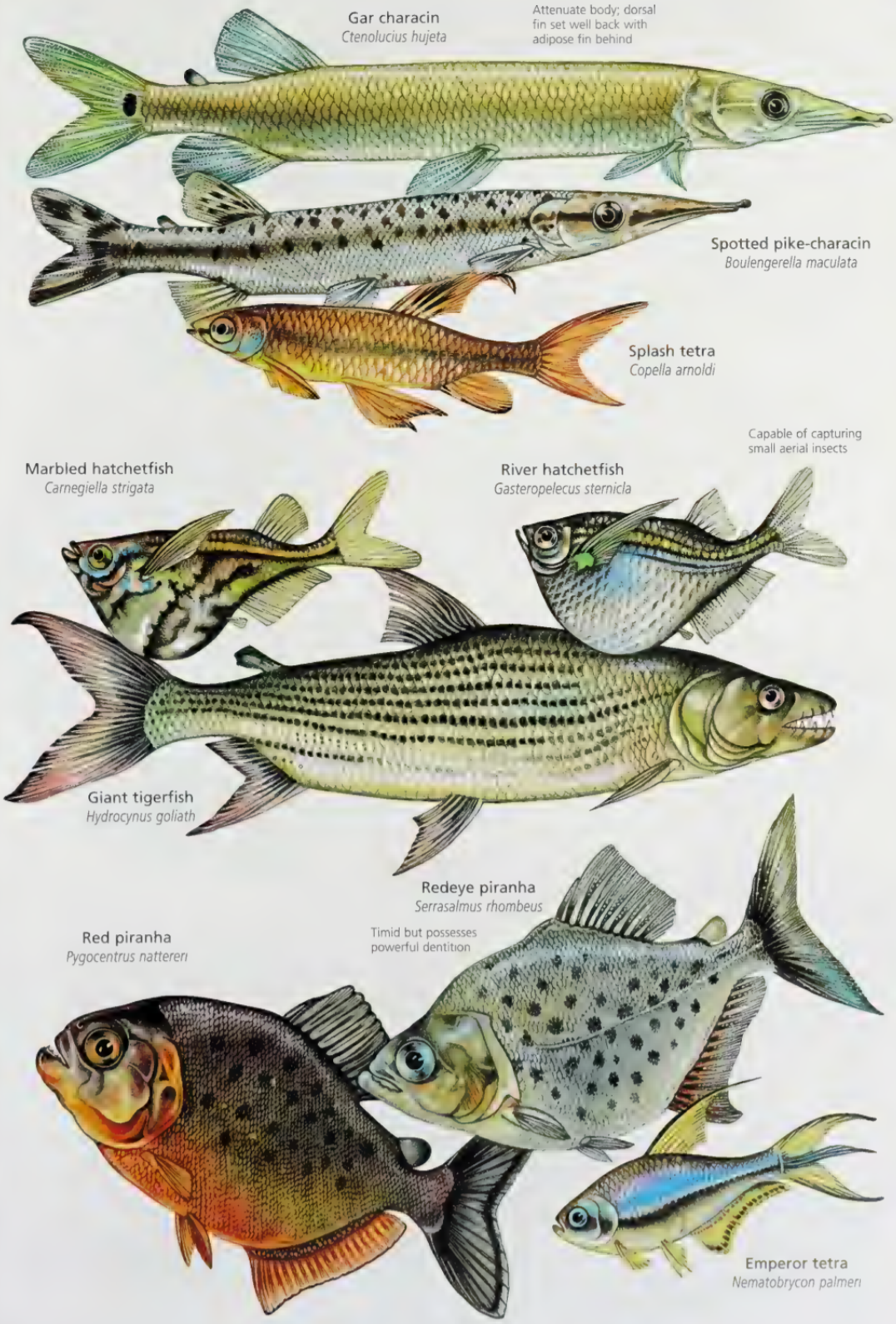
China (Yangtze River basin)

**Reticulate loach** A tropical, Asian freshwater species, this fish is also commonly known as the Pakistani loach. It is a nocturnal feeder with an omnivorous diet of mainly bottom-dwelling invertebrates, such as snails and worms, as well as algae. When threatened, it will rapidly bury the front end of its body in sediment leaving only its tail exposed

Up to 4¾ in (12 cm)
Up to 4 oz (115 g)
Oviparous, hiders
♀♂ Male & female
Common

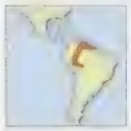
Pakistan, India, Bangladesh, Nepal

**Stone loach** A nocturnal bottom-dweller with three pairs of barbels, the stone loach feeds on benthic invertebrates. Because of its sensitivity to pollution and low levels of dissolved oxygen, it is regarded as a good biological indicator of water quality.




## FACT FILE

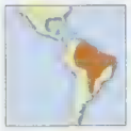
**Marbled hatchetfish** The distinctively shaped body of Amazonian hatchetfishes contains well-developed muscles to support enlarged pectoral fins, used for flying above water to escape predators. These fishes are surface feeders and this species is thought to consume plant material, including flowers, as well as insects



Up to 1½ in (3.4 cm)
Up to ½ oz (15 g)
Oviparous
♀♂ Male & female
Common

N. South America

**Red piranha** The reputation of this fish, the most notorious of South America's piranhas, is exaggerated. It certainly forms the feeding frenzies for which piranhas are famous but only in the dry season when numbers are concentrated in shrinking water holes. Piranhas' highly developed hearing is crucial to prey detection.



Up to 14 in (36 cm)
Up to 2½ lb (1.1 kg)
Oviparous, guarders
♀♂ Male & female
Common

N.E. South America

## SPLASH TETRA

Splash tetras avoid aquatic egg-eaters by spawning out of water. Females leap into the air and, as their wet bodies stick to overhanging leaves, deposit up to eight eggs at a time before falling. Males follow quickly and the pair interlock fins to hang from the leaves as the male deposits his sperm The procedure is repeated until several hundred fertilized eggs are laid. Tail flicks from males keep the eggs moist until fry hatch and fall into the water

## FACT FILE

**Striped eel-catfish** [illegible] species. The eel-catfish [illegible] swim with their right sides [illegible] position. The backing [illegible] fish are spiked with [illegible] their [illegible] depth of [illegible].

**Glass catfish** [illegible] a popular aquarium fish because [illegible] transparent body. [illegible] species [illegible] and [illegible]. Glass catfish are [illegible] in the wild but [illegible] that is a breeding [illegible] in [illegible] aquaria.

## PARASITIC BROODERS

[illegible] catfish is but one [illegible] known to practice this [illegible] breeding to another fish. [illegible] catfish doesn't [illegible] of mouth-brooding [illegible] eggs [illegible] catfish [illegible] in the [illegible] mouth. In the female [illegible] catfish [illegible] the eggs [illegible] mouth, the eggs [illegible] catfish [illegible]. The catfish's head [illegible] grow [illegible] and [illegible] [illegible] [illegible]

Electric catfish
*Malapterurus electricus*

Blotched upsidedown catfish
*Synodontis nigriventris*

Angel squeaker
*Synodontis angelicus*

Spotted hoplo
*Megalechis thoracata*

Pictus cat
*Pimelodus pictus*

Masked corydoras
*Corydoras metae*

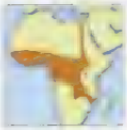
Barred knifefish
*Steatogenus elegans*

Black ghost
*Apteronotus albifrons*

Electric eel
*Electrophorus electricus*

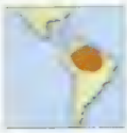
## FACT FILE

**Electric catfish** With modified muscle around its body capable of delivering about 400 volts, this nocturnal African species generates electric shocks to stun prey and deter predators.



New River & Central Africa

**Electric eel** A South American native, the electric eel is unrelated to true eels but is a relative of piranhas and tetras. It is unable to absorb sufficient oxygen through gills and gulps air to breathe by going to the mouth, which is richly lined with blood vessels, as a lung.



S South America

## CANDIRU

The candiru, a catfish that grows to just 1 inch (2.5 cm) in length, feeds a uniquely parasitic lifestyle. Found in the fast water of the Amazon, it swims into gill cavities of larger fish to feed on blood. It has been known to enter and lodge in the urethras of unwaring human bathers, causing hemorrhaging and sometimes even death.

## ELECTRIC EELS

Most of an electric eel's body is a raw endowed with many thousands of electricity-producing cells derived from modified muscle tissue. This fish navigates by generating and sensing weak electrical discharges. But it also uses powerful intense electricity, which at up to 500 volts, is large enough to stun human and a horse.

# SALMONS AND ALLIES

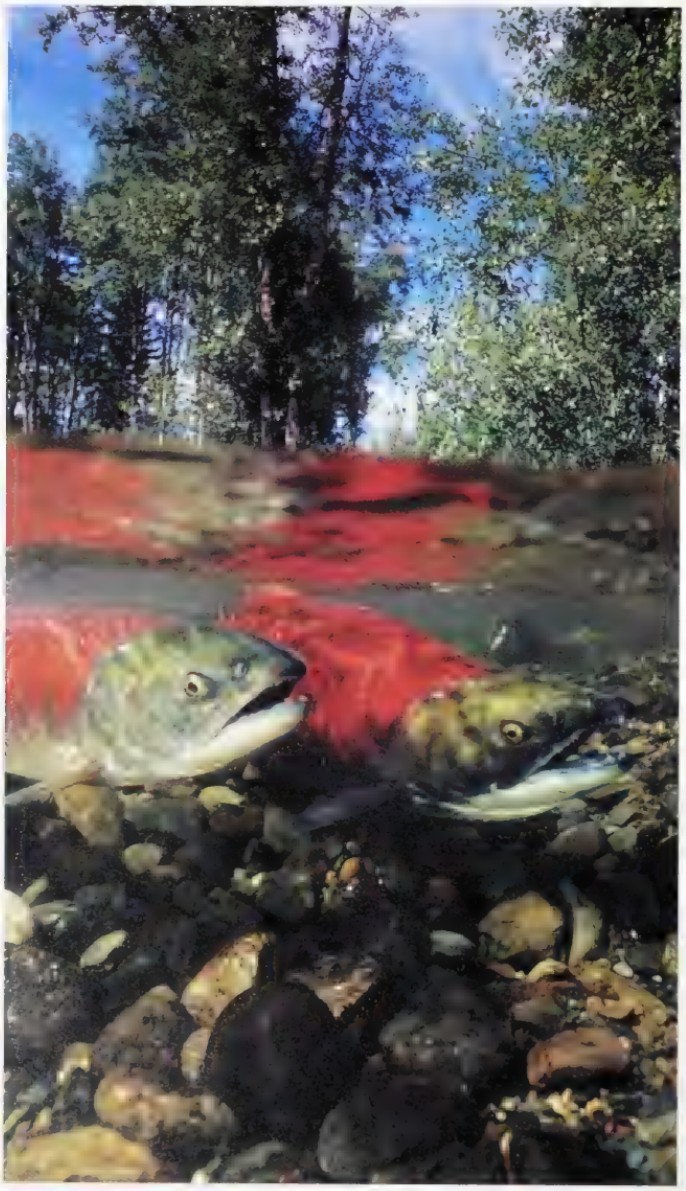
CLASS Actinopterygii
SUPERORDER Protacanthopterygii
ORDERS 3
FAMILIES 15
SPECIES 502

Some of the world's most sought-after angling and table fishes are among this group, the protacanthopterygians, which has ancient origins stemming back to the cretaceous (144–65 million years ago). It is usually divided into 15 families comprising more than 500 species arranged into three groups: esociforms, osmeriforms, and salmoniforms. These fishes are mostly carnivores equipped with large mouths and sharp teeth. Many are powerful and agile swimmers with elongate, streamlined bodies and well-developed tail fins. This swimming prowess is particularly evident in the salmons and trouts, many of which make extraordinarily long and arduous spawning migrations, journeys that have perplexed and fascinated scientists for centuries.

**Expanding distribution** Esociforms are found only in temperate North America, Europe, and Asia. Osmeriforms are also temperate fishes, with representatives in both hemispheres. The salmoniforms are Northern Hemisphere natives but many species have been introduced into suitable temperate-water ponds, streams, and rivers worldwide for the purposes of recreational angling and aquaculture

**Trout farming** Several trout species particularly rainbow trout (*Oncorhynchus mykiss*) are farmed in temperate areas in both purpose-built ponds and netted enclosures within natural water courses. These are stocked with fry obtained by artificial fertilization from hatcheries and grown to marketable size on a diet of pellets derived as a by-product from the meat-packing industry

Voracious carnivores



**Migratory marvels** Each stream has a distinct odor created by the soil and vegetation in its drainage. It is believed that this may become imprinted on young salmon and help them to find their way home during spawning migrations

## DIVERSE PREDATORS

The esociform group includes the pikes, muskellunge, pickerels, and mudminnows, all of which lead exclusively freshwater lives. Most are formidable ambush predators and the location of the median fins back toward the tail is an adaptation to this lifestyle.

There are more than 230 species of osmeriforms. Among the most bizarre are the barreleyes, which have upward-directed tubular eyes and other specialist adaptations for life in the high-pressure darkness of oceanic depths. Commercially important osmeriforms include the Northern Hemisphere's smelts—small, streamlined fishes that are particularly abundant in temperate coastal waters. In the Southern Hemisphere, the best-known osmeriforms are the galaxiids, a scale-less family with complex lifecycles in which juvenile stages move between fresh and saltwater.

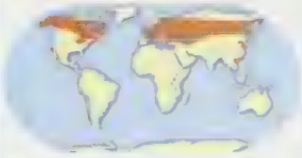
The salmoniforms include the whitefishes, ciscoes, graylings, chars, salmons, and trouts. Most are commercially important but it is the homing and migratory capabilities of the salmons that attract particular attention.

The six species of Pacific salmons spend most of their lives at sea but all attempt to return to the freshwater streams in which they were spawned when they reach sexual maturity. The sense of smell is believed to be critical to these fishes in locating their birthplaces.

## FACT FILE

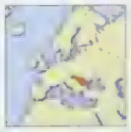
**Northern pike** Important as a food and angling fish, the northern pike is found across the most northerly reaches of North America, Europe, and Asia. This circumpolar occurrence is the widest natural distribution of any exclusively freshwater fish

- Up to 4½ ft (1.4 m)
- Up to 75 lb (34 kg)
- Oviparous
- ♀♂ Male & female
- Common



North America and N. Eurasia

**Mudminnow** Habitat destruction, pollution, and competition from introduced fishes are threatening the future of Eastern Europe's mudminnow. This fish will gulp in atmospheric air when dissolved oxygen levels drop in surrounding waters



- Up to 5 in (13 cm)
- Up to 5 oz (140 g)
- Oviparous, guarders
- ♀♂ Male & female
- Vulnerable

E. Europe

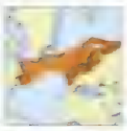
### PIKE TEETH

A pike's lower jaw is studded with a single row of numerous, needle-like teeth. Their acute points and razor-sharp edges pierce and cut prey as the fish lunges at speeds of up to 30 miles per hour (48 km/h). Backward-curved teeth on the roof of the mouth hold prey in place to prevent escape. Pike frequently attack prey as big as themselves and are sometimes seen swimming with half-digested meals protruding from their mouths

special recurved teeth on roof of mouth hold prey in place

## FACT FILE

**Atlantic salmon** [illegible]



[illegible]

**Sea trout** [illegible]

[illegible]

**Brown trout** [illegible]

[illegible]

**European smelt** [illegible]

[illegible]

Chum salmon
Oncorhynchus keta

Males have larger front teeth than other salmon

Chinook salmon
Oncorhynchus tshawytscha

Coho salmon
Oncorhynchus kisutch

White gums at base of teeth

Sockeye salmon
Oncorhynchus nerka

Pink salmon
Oncorhynchus gorbuscha

Cherry salmon
Oncorhynchus masou

Rainbow trout
Oncorhynchus mykiss

Golden trout
Oncorhynchus aguabonita

Mature males also large pale spots on back and sides

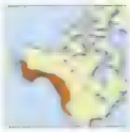
## FACT FILE

**Pink salmon** Young pink salmon spend very little time in fresh water, migrating to the sea almost immediately after they hatch. They return, after 18 months, to spawn in the same fresh water in which they were born, after which they die.

- Up to 30 in. (76 cm)
- Up to 15 lb. (6.8 kg)
- Dorsal fins, tail, back
- Male & female
- Common

Arctic Ocean, N.E. Asia, N.E. North America

**Rainbow trout** This fish has become a freshwater favorite of fly-fishing anglers in the many parts of the world where this species has been introduced. However, some native North American rainbow trout actually migrate to the sea as adults and then return to fresh water to spawn.



Pacific Ocean, Americas, Hawaii, Japan

## LIFE-CYCLE OF SOCKEYE SALMON

Eggs are laid in gravel nests dug by females. Alevin hatch with yolk-sac still attached, but a few days later become free-swimming fry. They develop into parr, which can remain in fresh water for several years before entering sea (parr are silvery smolt and develop into large sea-going adults). Both sexes return to fresh water with red bodies and green heads. Mature males also develop hunched backs and hook-shaped jaws.

The mature salmon may also return to spawning ground a few months after, but most they have fallen over, or [illegible]

## FACT FILE

**Lake trout** This deep-dwelling, light-shunning, freshwater species feeds on other fishes, crustaceans, and aquatic insects. Females have been crossed in hatcheries with males of the brook trout (*Salvelinus fontinalis*) to produce fast-growing hybrids known as splakes.

Up to 4 ft (1.2 m)
Up to 70 lb (32 kg)
Oviparous
♀♂ Male & female
Common

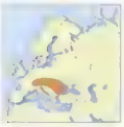
N. North America

**Grayling** Found in unpolluted streams, lakes, and occasionally brackish water throughout northern Europe, graylings spawn en masse during the northern spring when males dig nests into which females bury fertilized eggs. Grayling adults' diets consist mainly of aquatic invertebrates, particularly insects.

Up to 23½ in (60 cm)
Up to 6½ lb (3 kg)
Oviparous, hiders
♀♂ Male & female
Common

N. Europe

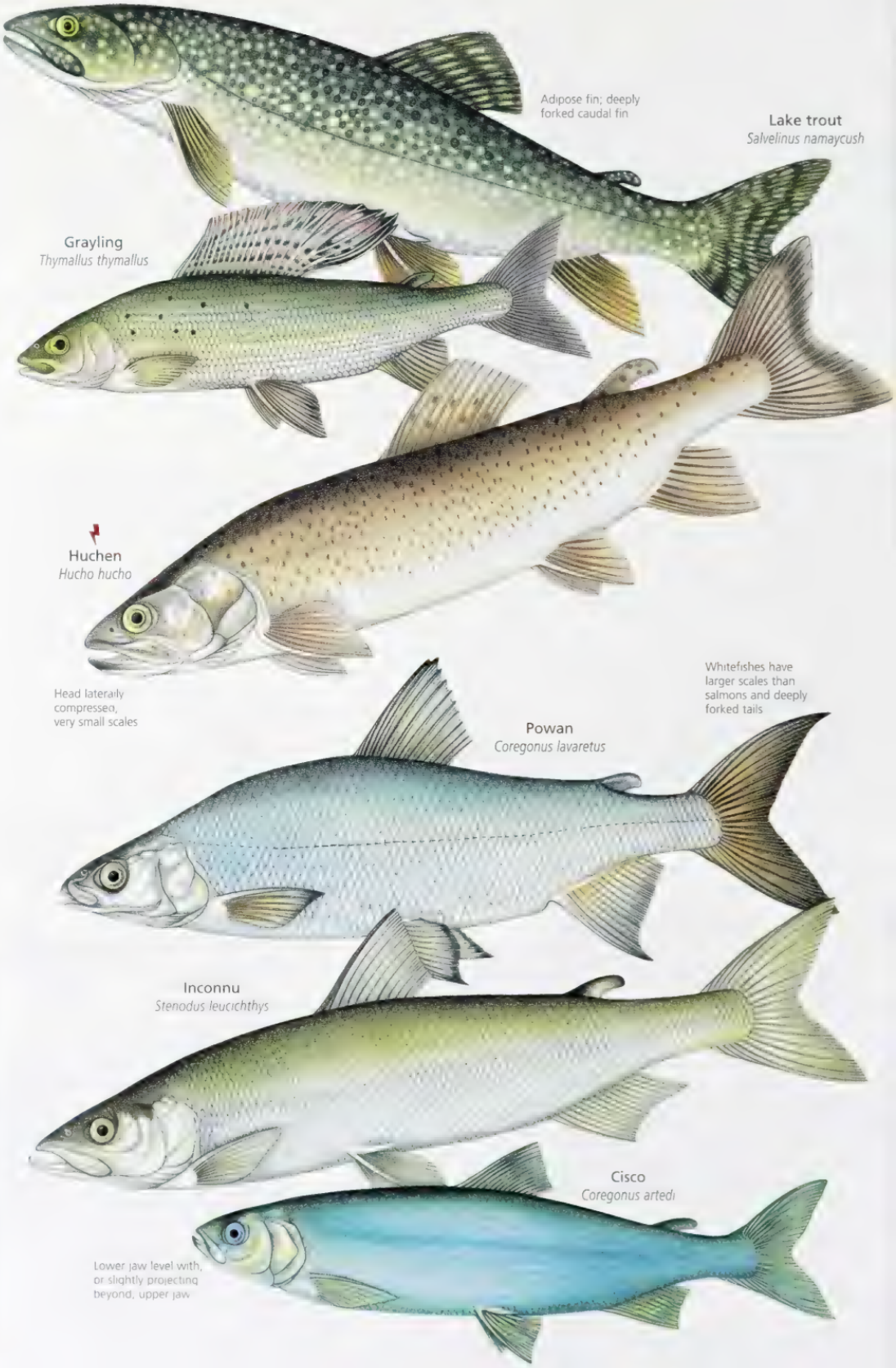
**Huchen** The huchen is one of the world's largest freshwater fishes. Adults are territorial predators that eat other fishes as well as frogs, reptiles, birds, and even small mammals. Its popularity with anglers, pollution, and the damming of the fast-flowing waterways it inhabits have all contributed to its endangered status.



Up to 5 ft (1.5 m)
Up to 46 lb (21 kg)
Oviparous, hiders
♀♂ Male & female
Endangered

## CONSERVATION WATCH

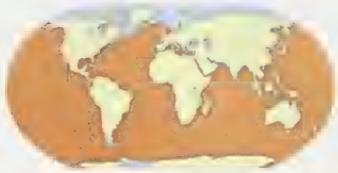
**Disappearing galaxiids** The IUCN lists 68 protacanthopterygians, including five that have already gone extinct. Among the eight listed as critically endangered are four galaxiids, each with exceptionally limited freshwater Australian distributions and all threatened by introduced fishes and habitat destruction. Until 1996, one—the pedder galaxias (*Galaxias pedderensis*)—was considered to be among the world's most endangered fishes. Conservation efforts based on the translocation of individuals to a secure lake, however, appear to have now assured the future of the pedder galaxias.



# DRAGONFISHES AND ALLIES

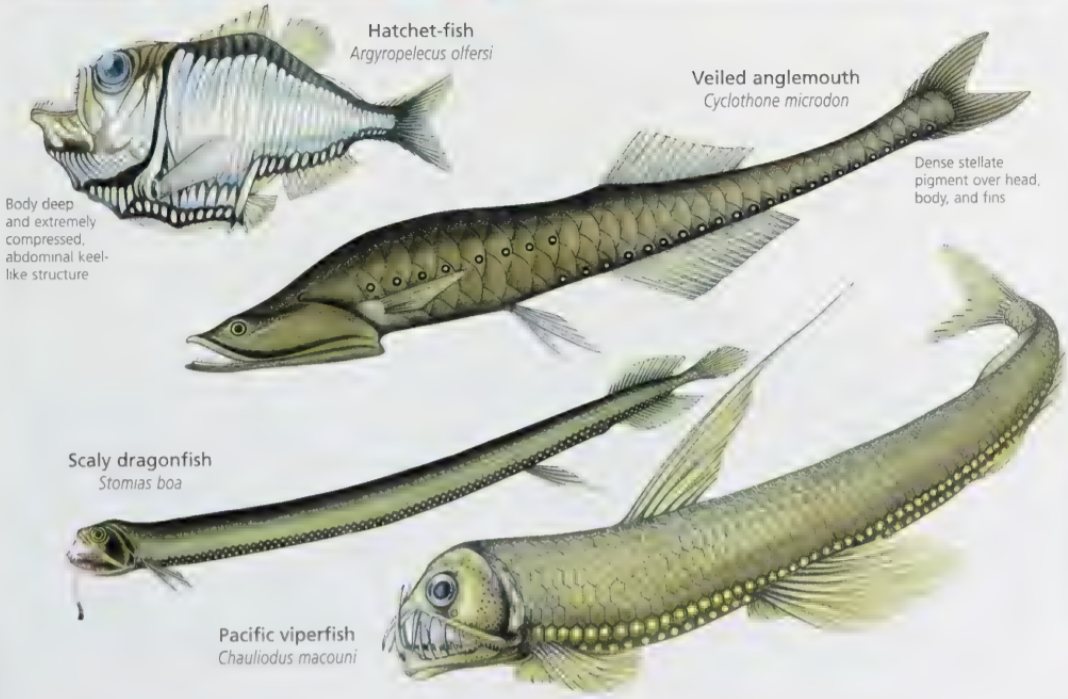
**CLASS** Actinopterygii
**SUPERORDER** Stenopterygii
**ORDERS** 2
**FAMILIES** 5
**SPECIES** 415

Although diverse and widespread, the stomiiforms are rarely encountered by people because of their mid- to deep-water lifestyle. All are predators that are adapted to habitats defined by high pressure, limited light, and low productivity. Most have long teeth and big mouths that can cope with large, infrequently encountered meals. And all but one species are equipped with light organs—photophores. Dotted along their sides and underbellies, these serve as camouflage from predators below by masking their appearance against weak light from above. Most also use them for hunting; suspended from a chin barbel or fin ray they lure prey like moths to a flame.



**Deep-sea distribution** The stomiiforms are found in the deep, open waters of all major temperate and subtropical oceans. Some extend into polar waters. They are also found over a large depth range, migrating upward at night and returning down during the day.

**Fierce predator** This deep-sea dragonfish (*Idiacanthus* sp.) has features typical of the family Stomiidae, including photophores along its belly and a long barbel on the lower jaw. These fishes remain in the complete darkness of the ocean's extreme depths by day, but migrate vertically at night to feed at more moderate depths. Males of this genus are much smaller than the females and lack teeth and pelvic fins.




## DEEP-SEA LIFE

Stomiiforms typically have big heads, long bodies, and dark coloration, although some are translucent or silvery. Common names such as lightfishes, bristlemouths, loosejaws, snaggletooths, and viperfishes suggest their often bizarre appearance.

Hermaphroditism is common, an adaptation to a habitat where members of the same species may be infrequently encountered.

Eggs and larvae are buoyant, floating within plankton in surface currents, but young descend as juveniles to pursue deep-sea life. As adults, many stomiiforms rest by day in deep water but migrate at dusk to shallower depths, where food in the form of small fishes and invertebrates is more plentiful.

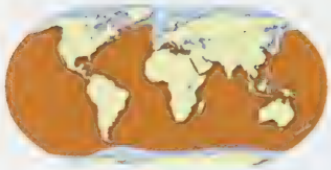
### CONSERVATION WATCH

**Deep questions** Because deep-sea habitats can be as inaccessible as outer space, very little is known about the population structure, size, or breeding behavior of the stomiiforms. It is possible that one genus, *Cyclothone*, includes more individuals than any other vertebrate genus, because of these tiny, mesopelagic fishes live in the oceans. It is also possible that some are disappearing as a consequence of oceanic pollution before their existence has even been recorded.

# LIZARDFISHES AND ALLIES

CLASS Actinopterygii
SUPERORDER Cyclosquamata
ORDER Aulopiformes
FAMILIES 13
SPECIES 229

This marine group, the aulopiforms, is represented in both coastal habitats and great depths. It includes the lizardfishes, Bombay ducks, greeneyes, ipnopids, lancetfishes, daggertooths, and telescopefishes. They exhibit an unusual mix of primitive and advanced features and are of particular interest to scientists for various reasons, including their range of peculiar eye modifications. Many deep-sea species are notable for their mode of reproduction: they are bisexual synchronous hermaphrodites, which means that they function as both sexes at the same time and may even be capable of self-fertilization. The aulopiforms are also known for the often extreme metamorphoses they pass through as they change from larvae into juveniles.

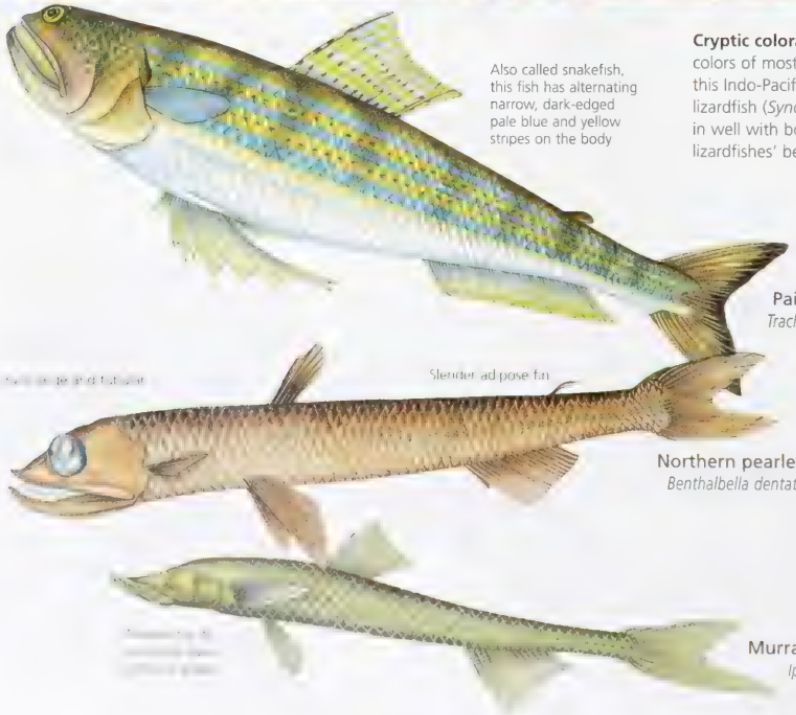


**Wide distribution** Lizardfishes occur in all warm seas. Greeneyes are found worldwide in tropical to warm-temperate waters Most Bombay ducks have an Indo-Pacific distribution. The lancetfishes range widely in Atlantic and Pacific mid-waters

ASSORTED ASSEMBLAGE
Lizardfishes, Bombay ducks, and greeneyes are inshore bottom-dwelling ambush predators. Typically well-camouflaged, they often sit propped up at the front end by their pectoral fins.

The ipnopids dwell at great depths and usually have flat heads, pencil-like bodies, and poorly developed eyes.

Attaining lengths of nearly 7 feet (2.1 m), lancetfishes are among the largest of all deep-sea predatory fishes. They have huge mouths and large, dagger-like teeth, and have a reputation for destroying undersea cables. They are sometimes seen floundering in the surf.



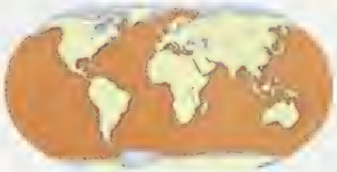

**Cryptic coloration** The patterns and colors of most lizardfishes, including this Indo-Pacific species, the variegated lizardfish (*Synodus variegatus*), blends in well with bottom sediments and the lizardfishes' benthic habitat

**Say cheese** Propped up on hugely elongated pelvic and tail fins, tripod fishes hold themselves clear of the substrate at great ocean depths awaiting prey. These ipnopid fishes grow to a maximum length of about 14 inches (36 cm)

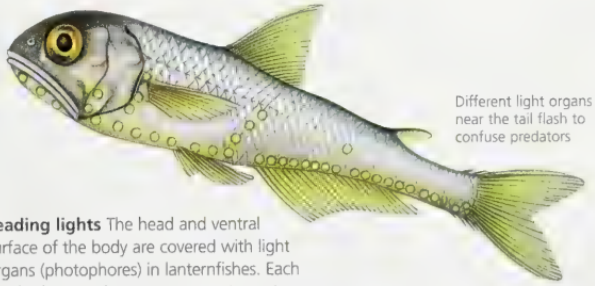
# LANTERNFISHES

**CLASS** Actinopterygii
**SUPERORDER** Scopelomorpha
**ORDER** Myctophiformes
**FAMILIES** 2
**SPECIES** 251

Of all the deep, open-water marine fishes, the lanternfishes are the most widely distributed, diverse, and abundant. Because these small plankton-eaters form large dense schools preyed upon by sea birds (particularly penguins), marine mammals, and a huge range of carnivorous fishes, they play a crucial role in virtually all marine ecosystems. They are fished to a relatively small extent for fish meal and oil but, with a global mass estimated at a staggering 660 million tons (600 million tonnes), they are otherwise regarded as a largely underused commercial resource. Together with their less abundant allies the neoscopelids, lanternfishes make up the group known as the myctophiforms.



**Global resource** Lanternfishes can be found in all open oceanic waters. Species distributions are related to both ocean currents and the physical and biological characteristics of the water. Many exist at great depths by day but will migrate upward to feed in surface waters by night



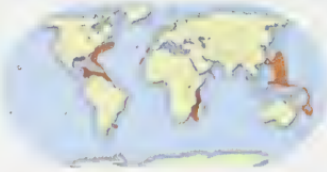

**Leading lights** The head and ventral surface of the body are covered with light organs (photophores) in lanternfishes. Each species has a unique arrangement, creating patterns that may be used as identifying signals to assist shoaling. Tail photophores may play a role in sex recognition.

Metallic lanternfish
*Myctophum affine*

# BEARDFISHES

**CLASS** Actinopterygii
**SUPERORDER** Polymixiomorpha
**ORDER** Polymixiiformes
**FAMILY** Polymixiidae
**SPECIES** 10

Just 10 species in one genus make up this small but puzzling group of deep-water marine fishes, which derives its common name from the pair of sensory barbels they all have hanging from the chin. Like the more advanced teleosts (the spiny-rayed fishes), they have true fin spines (as opposed to soft rays): between four and six in the dorsal fin and four in the anal fin. However, along with this modern feature they also exhibit several primitive and unique characteristics, creating a perplexing array of attributes that has fuelled much debate about which other fish groups are their closest relatives.



**Bottom dwellers** Beardfishes are known from tropical and subtropical oceanic waters. They live on the outer continental shelf and upper slope at various depths between 65 and 2,500 feet (20 and 760 m), usually on the bottom

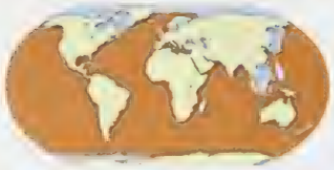
**Rare catch** This beardfish (*Polymixia berndti*) is mostly encountered as bycatch taken by commercial trawlers working the deep tropical and subtropical waters of the Indo-Pacific

Stout beardfish

# OPAHS AND ALLIES

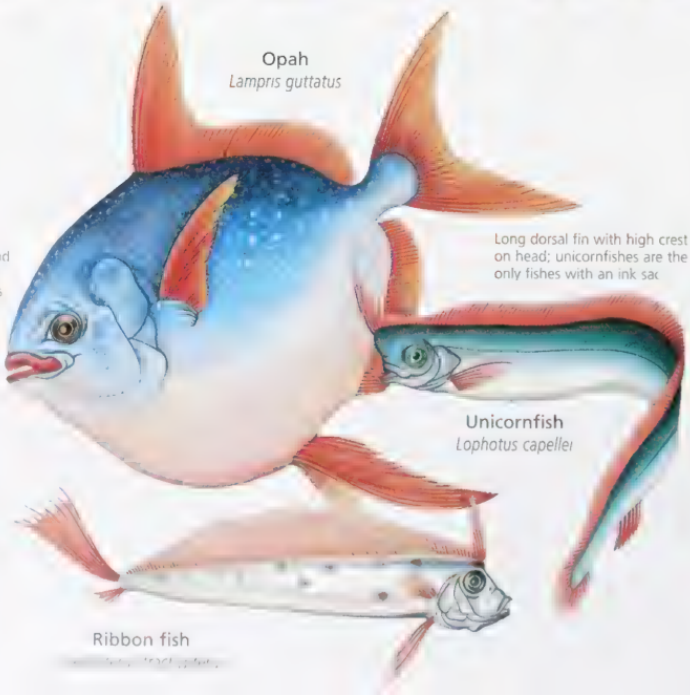
SUBDIVISION Euteleostei
SUPERORDER Lampridiomorpha
ORDER Lampridiformes
FAMILIES 7
SPECIES 23

Twenty-three species of deep-sea fishes, known as the lampridiforms, make up this group. Outwardly, their external appearance is extremely variable although most are either large and moon-shaped or elongated and snake-like. They all, however, share four unique and characteristic features, all but one of which relates to an unusual and specialized jaw arrangement that gives them highly protrusible mouths. They usually lack scales, tend to have dorsal fins that run the length of the body, and most have pelvic fins that are well forward on the body. Many have bodies adorned in radiant hues with bright red fins. This group probably arose some 65 million years ago.



**Widespread enigmas** Lampridiforms are usually found at depths of between 330 and 3,300 feet (100 and 1,000 m). Opahs, ribbonfishes, and tube-eyes have worldwide distributions in warm waters. Velifers are found only in the Indian and Pacific Oceans. The open-ocean, deep-water lifestyles of lampridiforms mean that they are rarely encountered by people.

**Mythical serpent** Accounts of sea monsters probably stem from sightings of the oarfish, the world's longest fish. There has been at least one report of a specimen measuring 56 feet (17 m) long but most probably attain lengths of around 26 feet (8 m). These fish usually inhabit depths up to 660 feet (200 m) but have been seen at the surface and washed up on beaches.




## CONSERVATION WATCH

**Enigmatic rarities** No species in this group are listed as endangered, but most are considered rare. Our lack of understanding about their true conservation status is just one of many areas in which our knowledge of these fishes is wanting. Most of what is known comes from tales of ancient mariners and the brief observations of captured and stranded individuals.

## STRANGE LIFESTYLES

The lampridiforms include the crestfish, opahs, ribbonfishes, tube-eyes, and velifers, some of which exhibit unusual feeding behaviors. The tube-eye *Stylephorus chordatus*, for example, rises hundreds of feet (meters) daily from depths of about 2,600 feet (800 m) to feed in a head-up, tail-down position on tiny crustaceans.

The ribbon fish *Trachipterus trachypterus* is thought to adopt a similarly vertical position to feed on other fishes and squid.

All lampridiforms produce large eggs, up to ¼ inch (6 mm) in diameter. Most are bright shades of red, which may protect against ultraviolet rays penetrating the surface waters in which they float for up to a month before hatching. Unlike the eggs of most bony fishes, which produce feeble larvae requiring a rich yolk sac for food, lampridiform embryos develop early and are vigorous swimmers.

# CODS, ANGLERFISHES, AND ALLIES

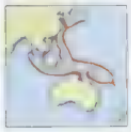
**SUBDIVISION** Euteleostei
**SUPERORDER** Paracanthopterygii
**ORDERS** 5
**FAMILIES** 37
**SPECIES** 1,382

Several small but significant features of the skeleton indicate relatedness between species in this group. There are also similarities in their habitat preferences. Most, for example, are bottom dwellers although some species (particularly those that are commercially important, such as haddock, hake, and the cods) form large pelagic schools. All but about 20 species comprising the group are marine. They tend to be active at night or live in dark habitats such as underwater caves or the deep sea. An unusual feature of some is that, by using special muscles located on the swim bladder, they can produce sounds. These may be important in courtship and communicating distress.

**Distribution** Cods and anglerfishes are found in all oceans. The cods are exclusively marine with the exception of one species—the burbot—which is found in freshwater. Troutperches and allies only live in freshwater and are restricted to North America. Toadfishes live along tropical coastlines.

## FACT FILE

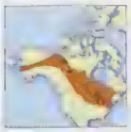
**Starry handfish** The expanded head of this dorsoventrally flattened bottom-dweller forms a flat rounded disc. It uses its hand-like pectoral fins, which project sideways from the back of this disc, to move across the substrate. An anglerfish, it carries a fleshy lure in a bony recess on the snout.



Up to 12 in (30 cm)
Up to 2 lb (900 g)
Oviparous
♀♂ Male & female
Common

Indo-West Pacific

**Trout perch** A native to freshwater streams and lakes in the eastern United States, the trout perch seeks rocky cover by day but ventures out by night to make short feeding migrations to shallower waters.



Up to 8 in (20 cm)
Up to 6 oz (170 g)
Oviparous
♀♂ Male & female
Locally common

N. North America

## CONSERVATION WATCH

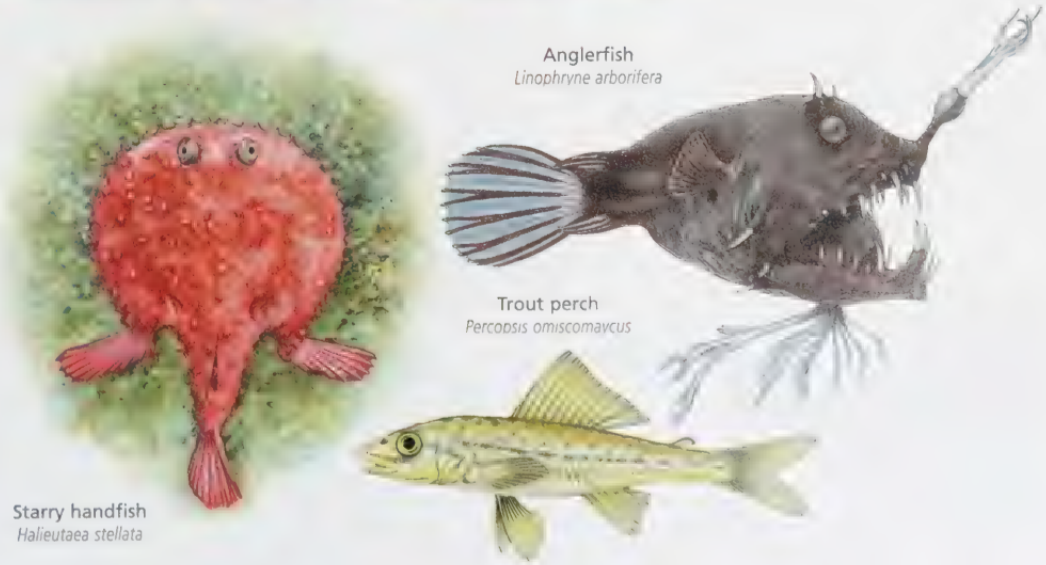
**Threatened futures** The critically endangered Alabama cavefish (*Speoplatyrhinus poulsoni*) is entirely white and blind. It occurs only in Key Cave, Alabama, in the United States. Interference with bat populations has indirectly affected the cavefish's food chain and the contamination of groundwater is another major threat. An introduced sea star and the increased silt in river sediments due to land clearing have almost certainly contributed to the critically endangered status of the spotted handfish (*Brachionichthys hirsutus*), a marine fish endemic to the Australian island of Tasmania.

## CRITICAL FOOD FISHES

Some of the most significant fisheries worldwide exploit species within the family Gadidae, which includes the Alaska pollock and Atlantic cod and annually accounts for well over 10 percent of the world's total fish catch.

These fishes produce enormous numbers of eggs, among the most of any fish. A large Alaskan pollock, for example, may spawn 15 million eggs in a year. Because, however, gadiform fishes are also long-lived and late to mature, they have proved to be highly susceptible to overexploitation and some fisheries are now in trouble.

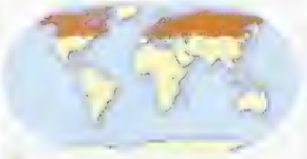
**Anglerfish** Many cod species are strong swimmers that actively search for prey along ocean substrates. Anglerfishes (left), in contrast, are mostly slow-moving and sluggish predators that wait for food to come to them. They can, however, move with lightning speed as they capture unsuspecting prey.



## FACT FILE

**Burbot** A freshwater lover of the dark with a circumarctic distribution, the burbot dwells mainly in the depths of lakes and slow-moving rivers. It shelters among vegetation, in suitable crevices, and down deep holes.

- Up to 5 ft (1.5 m)
- Up to 75 lb (34 kg)
- Oviparous
- ♀♂ Male & female
- Common



N. North America & N. Eurasia

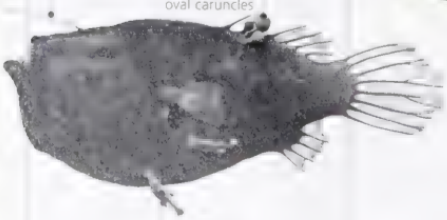
**European hake** After decades of commercial exploitation, there is widespread concern the European hake has been overfished. Although the maximum weight recorded for the species is about 25 pounds (11.5 kg), individuals over 11 pounds (5 kg) are now rarely caught

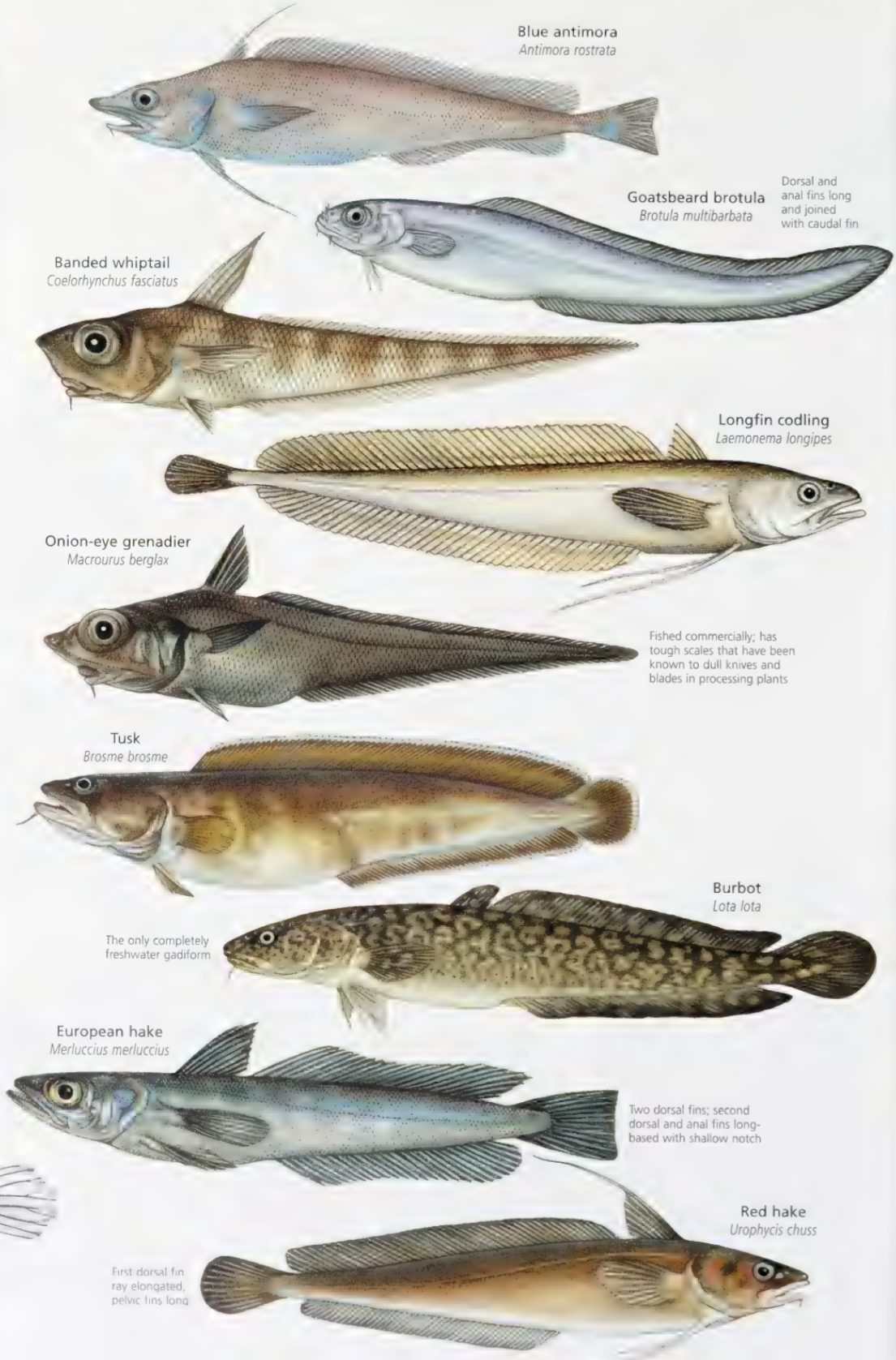
- Up to 4½ ft (1.4 m)
- Up to 25 lb (11.5 kg)
- Oviparous
- ♀♂ Male & female
- Common

E. North Atlantic, Mediterranean & Black seas

## SEXUAL PARASITES

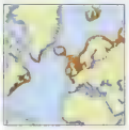
Ceratoid anglerfishes dwell in low-density populations in the high-pressure darkness of oceanic depths. To reduce the hit-or-miss probability of the sexes meeting, males of some species have evolved into little more than parasitic testes. As adults, they live permanently attached to and derive nourishment from their considerably larger female counterparts. In the triplewart seadevil (*Cryptopsaras couesii*) below, females have been found with up to four males attached



## FACT FILE

**Haddock** Both male and female haddock produce "knocking" sounds when threatened. Males become particularly raucous during spawning, so it is likely that their noises are significant in the haddock reproductive process



Up to 35½ in (90 cm)
Up to 18 lb (8.2 kg)
Oviparous
♀♂ Male & female
Vulnerable

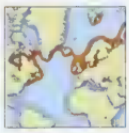
North Atlantic to Spitzbergen

**Angler** One of the anglerfishes, this eastern Atlantic species has an enormous mouth and lies in wait for prey, well-camouflaged among sand and sediment on the ocean floor. It usually feeds on other fishes but has been known to also take seabirds.

Up to 6½ ft (200 cm)
Up to 127 lb (58 kg)
Oviparous
♀♂ Male & female
Common

E. North Atlantic

**Atlantic cod** A cold-water species exploited in large commercial fisheries in the north Atlantic, this cod is usually caught at weights of about 25 pounds (11.5 kg) although it can grow to four times that size.



Up to 5 ft (1.5 m)
Up to 100 lb (45 kg)
Oviparous
♀♂ Male & female
Vulnerable

North Atlantic to Spitzbergen

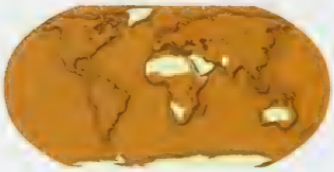
## EXQUISITE CAMOUFLAGE

Anglerfishes have no need for streamlining. Instead, these sit-and-wait predators are perhaps better served by being shaped and colored like their surroundings. The sargassumfish (*Histrio histrio*), for example, blends in with sargassum weed, and the roughbar frogfish (*Antennarius avalonis*) looks like a rock.

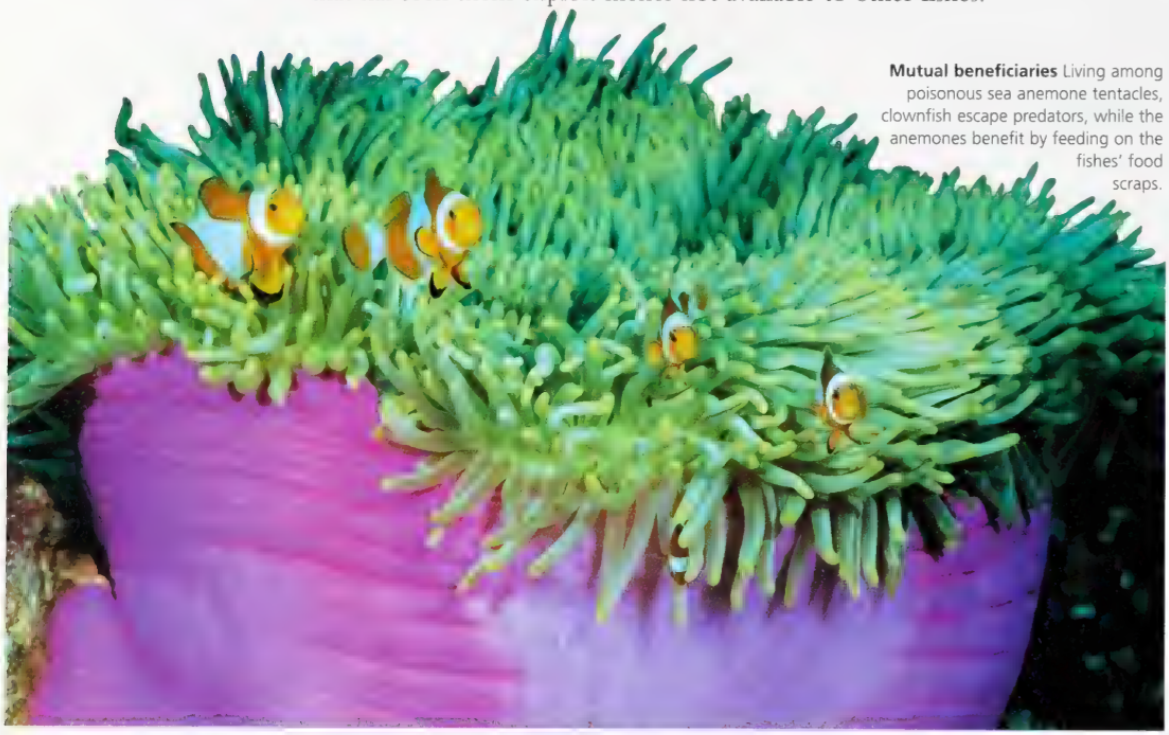
# SPINY-RAYED FISHES

| | |
|---|---|
| CLASS | Actinopterygii |
| SUPERORDER | Acanthopterygii |
| ORDERS | 15 |
| FAMILIES | 269 |
| SPECIES | 13,262 |

This, the largest single group of fishes, comprises the most advanced and recently evolved teleosts. Known also as acanthopterygians, the spiny-rayed fishes include more than 13,000 species in over 250 families. Common characteristics include a highly mobile and protrusible upper jaw, which has facilitated a wide range of feeding strategies, ctenoid scales that in some cases have become lost or further developed into hardened plates, and hard spines in the fins. As a group, these fishes have a ubiquitous distribution but are particularly abundant in coastal marine waters. They display an enormous breadth of specialized reproductive, behavioral, and anatomical adaptations that has seen them exploit niches not available to other fishes.



**Extensive distribution** The most widespread of all fish groups, the spiny-rays are found in almost every available aquatic habitat throughout the world from fresh water, through brackish to salt water, and from coastal shallows to the ocean's depths. Specialized morphological and behavioral adaptations allow them to inhabit a wide range of environments, from frozen seas to ponds that dry up



**Mutual beneficiaries** Living among poisonous sea anemone tentacles, clownfish escape predators, while the anemones benefit by feeding on the fishes' food scraps.

## ADVANCED ADAPTATIONS

Almost every variation on the basic fish body plan can be found among the spiny-rayed fishes. The flatfishes, for example, depart dramatically from the normal symmetry seen in most fishes. The wrasses and parrotfishes have a modified pharyngeal apparatus that acts as a second set of jaws in the throat, facilitating specialized feeding.

The cyprinodontiforms include guppies, swordtails, and other highly resilient freshwater aquarium favorites. Silversides can form large marine schools and many are commercially important baitfish. The flyingfishes are remarkably adapted for above-water gliding.

Gobies are mostly small fishes, such as the amphibious mudskippers, in which the pelvic fins are fused to form a cup-shaped disk.

In many of the triggerfishes and their relatives, scales have developed into protective body armor.

Damselfishes, including the well-known clownfishes, often display highly developed territorial behavior. The cichlids take parental care to its extreme. The groupers are among the most robust of all marine predators, and billfishes such as marlin and sailfish are among the fastest swimming.

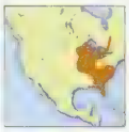
The scorpionfishes include some of the deadliest fishes to humans. The drums and croakers make deep distinctive noises when threatened and the butterflyfishes and angelfishes are among the most exquisitely colored aquatic creatures.

**Sexual variety** The spiny-rayed fishes display a wide range of sexual strategies [illegible] monogamy and male pregnancies are [illegible] sexual features seen in sea-[illegible] reproduction. Few other fishes adopt [illegible]

**Masterful masquerade** With frilled leaf-like fins, the leafy seadragon is so well-camouflaged that neither prey nor predators can detect it among the seagrass and seaweed beds where it dwells

## FACT FILE

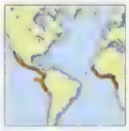
**Brook silverside** A native of subtropical North American freshwater lakes and rivers, this small translucent fish is usually found in schools near the water's surface, feeding on tiny crustaceans, insect larvae, and small flying adult insects. Spawning takes place in clear water, usually around vegetation, and each egg becomes anchored to the substrate by its own sticky filament.



Up to 5 in (13 cm)
Up to 4 oz (115 g)
Oviparous
♀♂ Male & female
Common

S.E. North America

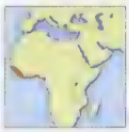
**Sharpchin flyingfish** Members of the genus *Fodiator* are among the weakest "flyers" of the flyingfish. Nevertheless, this species is capable of gliding over water on enlarged wing-like pectoral fins for 165 feet (50 m) or more. They live close to the surface of the open ocean, feed on plankton, and "fly" to evade attacks from predators below.



Up to 9½ in (24 cm)
Up to 8 oz (225 g)
Oviparous
♀♂ Male & female
Common

E. Pacific & E. Atlantic

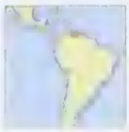
**Golden pheasant panchax** This shortlived freshwater species occurs in short-term pools and puddles in West African rainforest and humid forest. Adults die after spawning, at the onset of the dry season, leaving fertilized eggs to survive in mud for as long as 3 months. They hatch with the onset of the rainy season.



Up to 3 in (7.5 cm)
Up to 1 oz (30 g)
Oviparous, hiders
♀♂ Male & female
Common

W. Africa

**Saberfin killie** This is another short-lived species in which adults die not long after spawning. Left in drying mud, fertilized eggs enter a resting phase until they are stimulated to hatch by the first raindrops of the rainy season. There is virtually no larval period and the young are sexually mature in just over a month after hatching.



Up to 1½ in (4 cm)
Up to .5 oz (15 g)
[illegible] hiders
[illegible]
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Venezuela

## FACT FILE

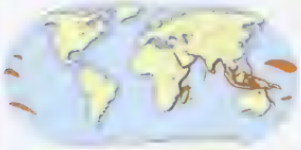
**Guppy** The guppy belongs to one of the few bony fish families (Poeciliidae) with members that give birth to live young. Originally from South America, this popular aquarium fish has been introduced to warm freshwater lakes throughout the world. This is an adaptable species that tolerates a wide range of habitats and water quality.

- Up to 2 in (5 cm)
- Up to ¼ oz (20 g)
- Viviparous; live bearers
- ♀♂ Male & female
- Common

N.E. South America, Barbados, Trinidad; introd. widely

**Crown squirrelfish** Most adult squirrelfishes live in shallow water around tropical reefs but their larvae have a long pelagic life and are often found way out to sea. This species has a short venomous cheek spine. Squirrelfishes are active at night, sheltering in caves and under ledges during the day. They feed on small fishes and invertebrates.

- Up to 6½ in (17 cm)
- Up to 8 oz (225 g)
- Oviparous
- ♀♂ Male & female
- Common



Indo-Pacific, Red Sea, Oceania

**Velvet whalefish** Named because of their whale-like appearance not their size, whalefishes are deep-sea ocean dwellers. They have reduced eyes but a highly developed lateral line system to provide information about their environment. They also have big mouths and highly distensible stomachs to cope with the large, infrequently encountered meals typical of life in the deep sea.

- Up to 14 in (36 cm)
- Up to 16 oz (450 g)
- Not known
- ♀♂ Not known
- Common

Three-spined stickleback
*Gasterosteus aculeatus*

Ninespine stickleback
*Pungitius pungitius*

7–12 free spines in front of dorsal fin

Longspine snipefish
*Macrorhamphosus scolopax*

Compressed scaleless body; mouth at end of long tubular snout

Shrimpfish
*Aeoliscus strigatus*

Indo-Pacific boarfish
*Antigonia rubescens*

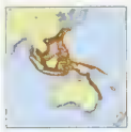
3 anal spines with 24–48 soft rays; body highly compressed

John Dory
*Zeus faber*

Massive head with large, highly protrusible jaws

## FACT FILE

**Shrimpfish** With a long-snouted, semi-transparent, shrimp-like body, this fish congregates in synchronized schools in a head-down, tail-up vertical position. It lives among sea urchins and staghorn coral branches and feeds on zooplankton. It has been found cast up on Indo-Pacific beaches after storms.

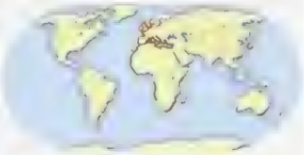


Up to 6 in (15 cm)
Up to 4 oz (115 g)
Oviparous
♀♂ Male & female
Common

Indo-West Pacific

**John Dory** The John Dory is a weak swimmer that leads a mostly solitary life near the ocean floor. A highly compressed body makes its head-on profile extremely narrow, helping it to remain hidden from prey as it stalks from behind. Its highly protrusible jaws are very efficient at capturing unsuspecting small fishes and crustaceans.

Up to 26 in (66 cm)
Up to 13 lb (6 kg)
Oviparous
♀♂ Male & female
Common



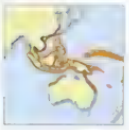
E. Atlantic, Mediterranean Sea, W. Pacific & W. Indian Ocean

## DEVOTED DADS

By cementing plants together with sticky secretions from their kidneys, male sticklebacks build elaborate nests for the females to lay their eggs in. After fertilizing the eggs, the males usually drive the females away but continue to maintain and defend the nests while attending to the eggs, fanning oxygenated water across them with their pectoral fins.

## FACT FILE

**Harlequin ghost pipefish** Pipefishes and seahorses have a series of bony plates beneath their skin. As a result, they cannot swim by flexing the body like most other fishes but use rapid fanning movements of the fins instead



Up to 4¼ in (12 cm)
Up to 1 oz (30 g)
Oviparous, brooder
♀♂ Male & female
Uncommon

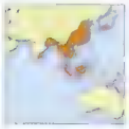
Indo-West Pacific

**Leafy seadragon** Like their close relatives the seahorses, male leafy seadragons incubate eggs. Females lay up to 250 onto a patch of spongy tissue on the tail's underside, where they develop for about 6 weeks before hatching.

Up to 16 in (40 cm)
Up to 8 oz (225 g)
Oviparous, brooder
♀♂ Male & female
Data deficient

S. Australia

**Swamp eel** This highly adaptable, air-breathing, freshwater carnivore that resembles an eel can survive out of water for long periods. It has been labeled a potential "ecological nightmare" in some areas to which it has been introduced

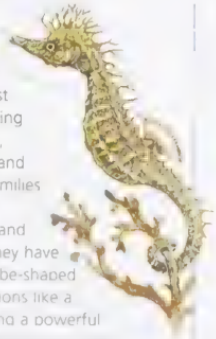


Up to 18 in (46 cm)
Up to 24½ oz (700 g)
Oviparous, guarders
♀♂ Hermaphrodite
Common

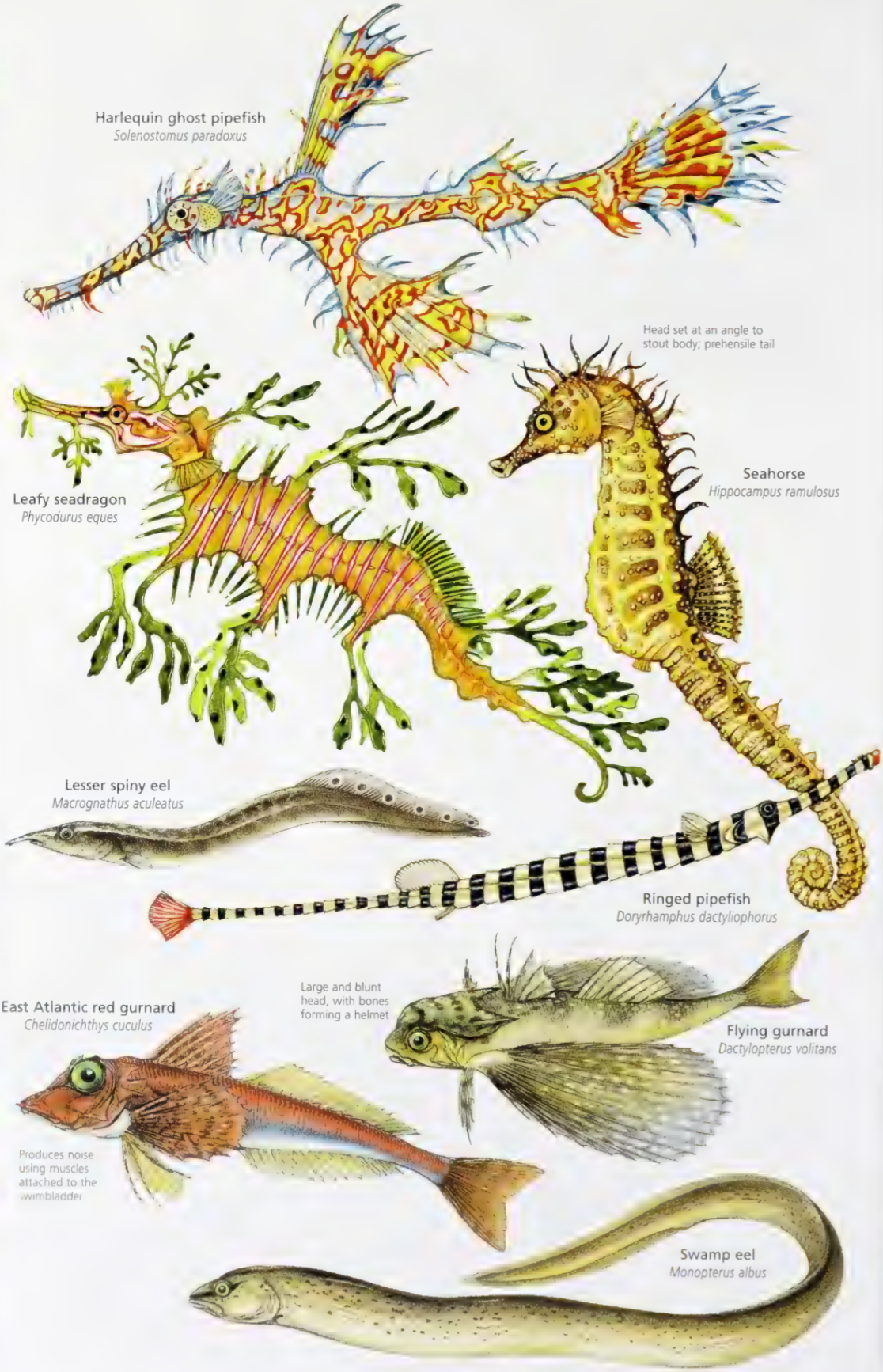
S.E. Asia, Australia

## SEAHORSE FEEDING

Seahorses are ambush predators that pluck mostly small, planktonic animals from the waters around them. Like their closest relatives, including the seadragons, trumpetfishes, and [illegible] pipefishes (families Syngnathidae, [illegible]nidae, and [illegible]ridae), they have [illegible] tube-shaped [illegible] functions like a [illegible] ing a powerful [illegible] draw in prey



*Toothless predators* [illegible]



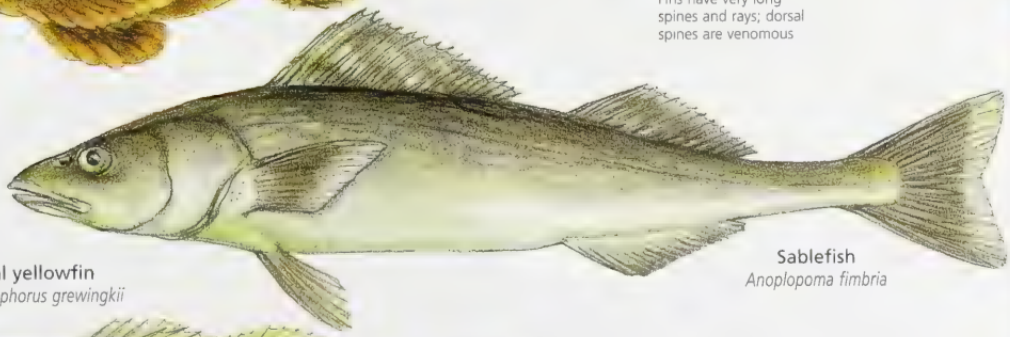
**Redfish**
*Sebastes marinus*

Eggs develop inside the female's oviduct; over several months, the female releases up to 20,000 larvae, each about ⅞ inch (8 mm) long

**Radial firefish**
*Pterois radiata*

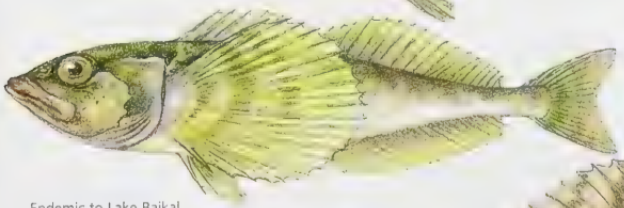
Fins have very long spines and rays; dorsal spines are venomous

**Stonefish**
*Synanceia verrucosa*



**Sablefish**
*Anoplopoma fimbria*

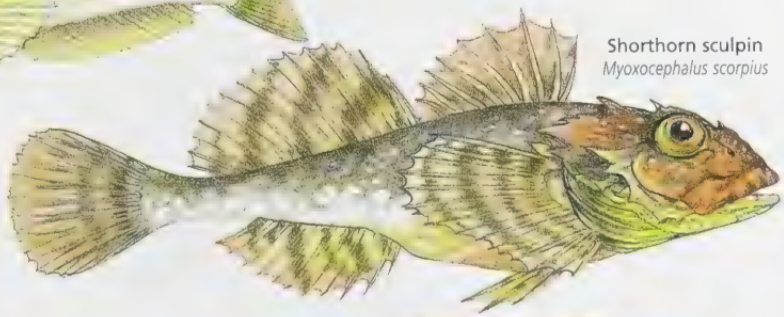
**Baikal yellowfin**
*Cottocomephorus grewingkii*



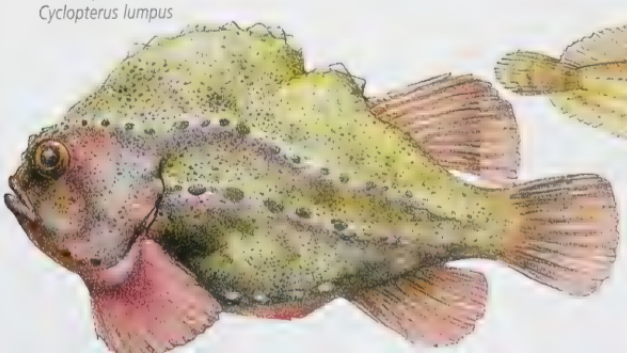
Endemic to Lake Baikal and its tributaries; huge pectoral fins

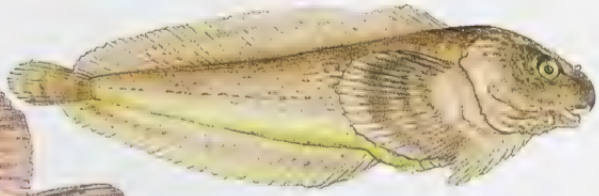
Spiny dorsal fin; head is also spiny

**Shorthorn sculpin**
*Myoxocephalus scorpius*



**Lumpsucker**
*Cyclopterus lumpus*

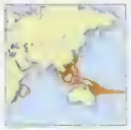




**Striped seasnail**
*Liparis liparis*

## FACT FILE

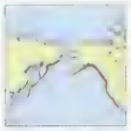
**Stonefish** Spines on the dorsal fin of this stonefish function like syringes to deliver agonizing stings and the most toxic venom produced by any fish. Deaths have occurred among people who have mistakenly walked on stonefish on reef flats.



Up to 14 in (36 cm)
Up to 4½ lb (2 kg)
Oviparous
♀♂ Male & female
Common

Indo-Pacific & Red Sea

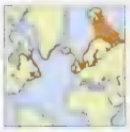
**Sablefish** Named because of its sleek black to dark-green skin, the sablefish is an important commercial species in Alaska and to a lesser extent in Canada. It is a deep-water, long-lived fish, with reports of individuals older than 90 years.



Up to 3¼ ft (1 m)
Up to 126 lb (57 kg)
Oviparous
♀♂ Male & female
Common

North Pacific

**Shorthorn sculpin** Renowned for eating "anything and everything," the shorthorn sculpin has a voracious appetite. Its large mouth can wrap around prey half its size and its stomach readily stretches around any large object it consumes.



Up to 24 in (60 cm)
Up to 2 lb (900 g)
Oviparous
♀♂ Male & female
Common

North Atlantic & Arctic oceans

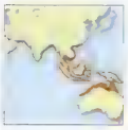
## LUMPSUCKER ANATOMY

The female lumpsucker deposits her large egg mass on the shore's edge near the low tide mark. The male guards it aggressively, maintaining his position in the turbulent intertidal zone by attaching to rocks or seaweed with a ventrally located sucking disk formed from modified pelvic fins

***Cheap treat***
*Lumpsucker eggs are sold commercially as inexpensive caviar*

## FACT FILE

**Barramundi perch** Most barramundi are protandrous hermaphrodites they begin life as males, reach sexual maturity after about 3 years, and become females after about 5 years. As a result, larger individuals are inevitably female, while smaller fishes are mostly males

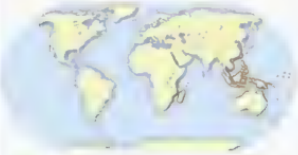


Up to 6 ft (1.8 m)
Up to 132 lb (60 kg)
Oviparous
Hermaphrodite
Common

Indo-West Pacific

**Sea goldie** The sexes in this fish look like different species. Females are colored orange to yellow while males are mainly purple. Males also have an enormously elongated dorsal fin spine and longer tail-fin lobes

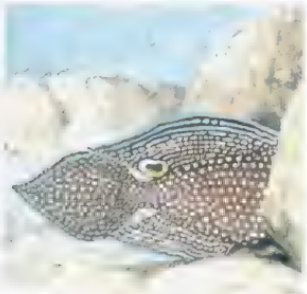
Up to 6 in (15 cm)
Up to 8 oz (225 g)
Oviparous
Sequential hermaphrodite
Common



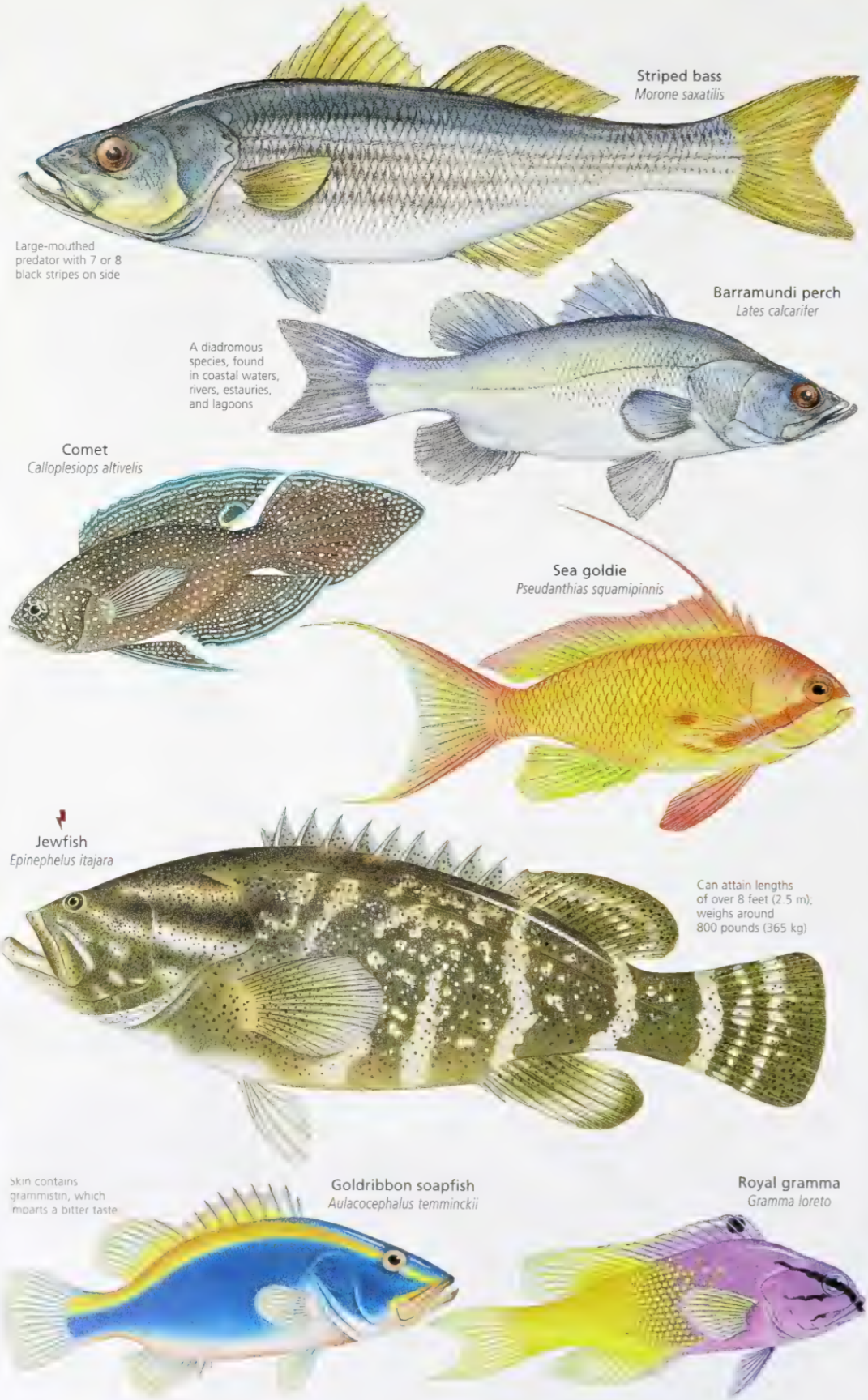
Indo-West Pacific & Red Sea

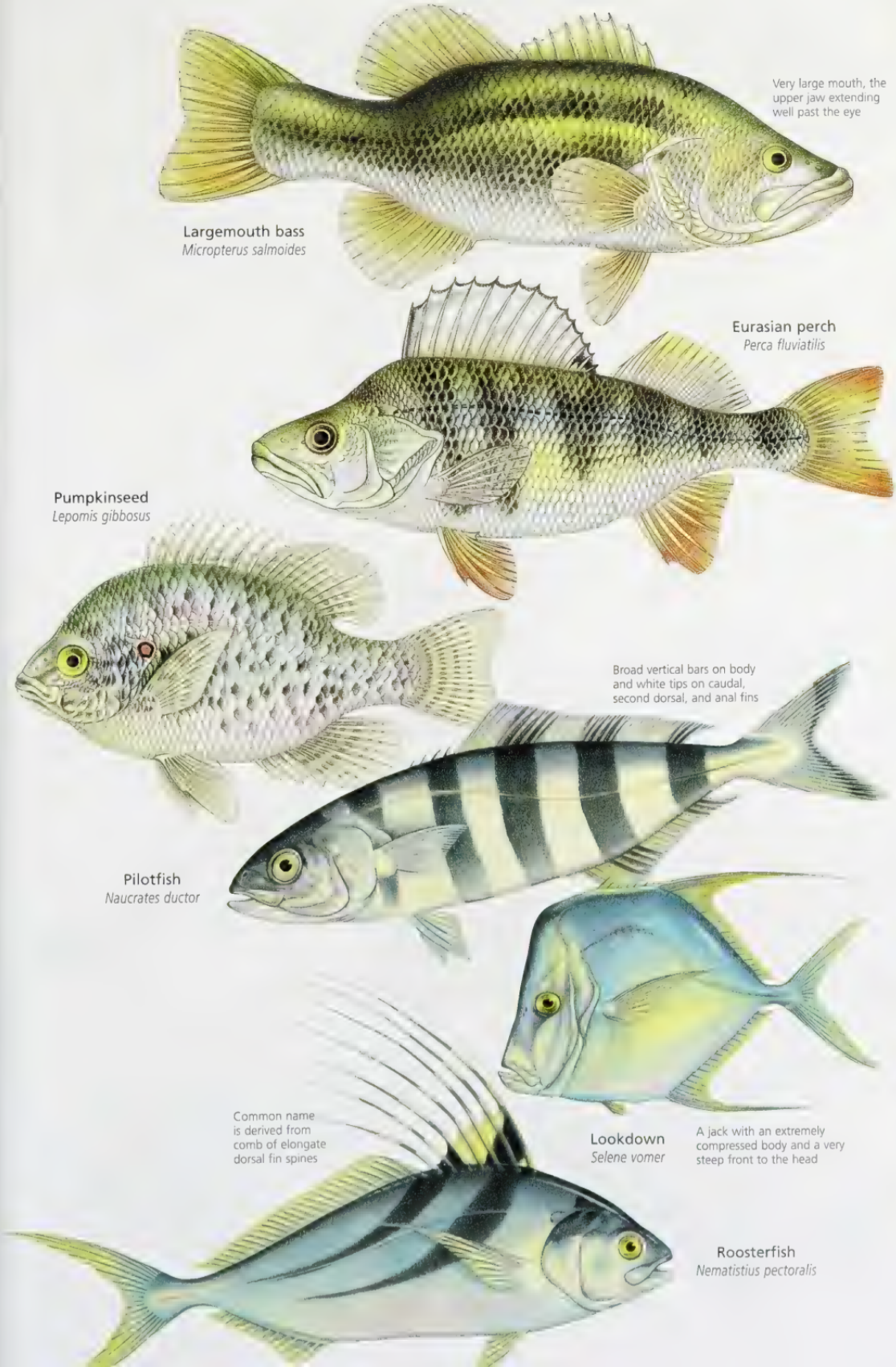
## INGENIOUS MIMICRY

The comet deters predators by hiding in holes exposing only its tail, which mimics the fierce-looking head of the identically patterned turkey moray eel (*Gymnothorax meleagris*). An ocellus at the base of the dorsal fin looks like an eye. A gap between the anal and tail fins forms a "mouth."



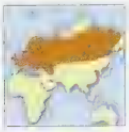
*Butterfly effect*






## FACT FILE

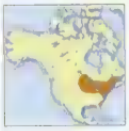
**Eurasian perch** The females of this species lay their eggs, several tens of thousands at a time, connected in long, white sticky mucous ribbons. These can be up to a meter in length and are left draped over submerged rocks and vegetation.



Up to 20 in (51 cm)
Up to 10½ lb (4.7 kg)
Oviparous
♀♂ Male & female
Common

N. Eurasia

**Pumpkinseed** As occurs within most species of the freshwater North American sunfish family, the male pumpkinseed is a nest-builder. Eggs and sperm are deposited as the male and female swim around the nest in a circular pattern. The male guards the eggs and larvae for about 11 days after hatching.

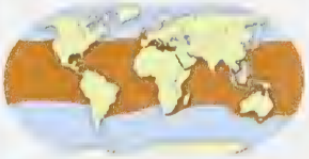


Up to 16 in (40 cm)
Up to 22 oz (630 g)
Oviparous, guarders
♀♂ Male & female
Common

E. North America; introd. widely

**Pilotfish** The common name of this species stems from its habit of swimming with sharks and other large marine creatures, feeding on food scraps and parasites. Sailors once thought they guided their "hosts" to food. Juveniles swim with jellyfish.

Up to 27½ in (70 cm)
Up to 15 lb (6.8 kg)
Oviparous
♀♂ Male & female
Common



Tropical seas worldwide

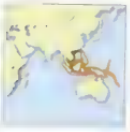
**Roosterfish** The roosterfish (Nematistiidae) is a jack-like fish and, like many species in the jack family (Carangidae), is a popular gamefish that fights strongly when hooked. Its distinctive, elongate, backward-curving dorsal spines look like a cockscomb

Up to 4 ft (1.2 m)
Up to 100 lb (45 k
Oviparous
♀♂ Male & femal

E.

## FACT FILE

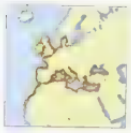
**Oriental sweetlips** The loose rubbery lips of sweetlips are adapted for "vacuuming" invertebrates from sandy bottoms. They feed so vigorously that silt sweeps back through their gill arches to emerge as a cloud in the water behind. Being a member of the circumtropical grunt family (Haemulidae), this species is also able to produce sounds by grinding its pharyngeal teeth



Up to 20 in (51 cm)
Up to 4 lb (1.8 kg)
Oviparous
♀♂ Male & female
Common

Indo-West Pacific

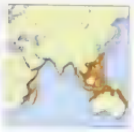
**Red mullet** This species is not a true mullet but a goatfish (family Mullidae). It has the long sensory chin barbels, characteristic of its family, and uses these to probe bottom sediments for small invertebrates. Goatfishes, like their mammalian namesakes, have a reputation for an omnivorous diet.



Up to 16 in (40 cm)
Up to 35 oz (1 kg)
Oviparous
♀♂ Male & female
Common

E. North Atlantic & Mediterranean Sea

**Emperor snapper** Juvenile emperor snapper live in shallow tropical waters, often in close association with sea urchins. Large adults, which dwell at greater depths, are sometimes implicated in cases of ciguatera poisoning. The vivid red stripes that characterize young fish of this species fade with age. Mature adults are colored red-pink all over

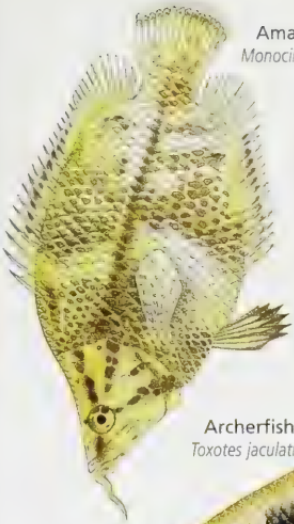


Up to 3¼ ft (1 m)
Up to 35½ lb (16 kg)
[illegible]
♀♂ Male & female
Common

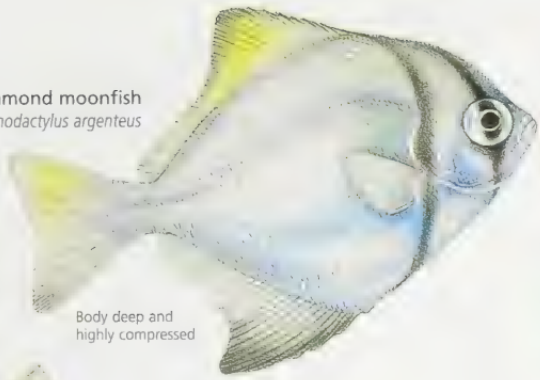
Indo-West Pacific, Red Sea

**Jack-knifefish** A greatly elongated dorsal fin gives this Caribbean endemic the most recognizable appearance of all the drums and croakers, a family of fishes (Sciaenidae) known for their [illegible]ty to produce sounds by resonating their highly specialized swim bladder [illegible] special muscles. This species is [illegible]nal, hiding in coral caves by day

Up to 10 in (25 cm)
[illegible]
[illegible]
♀♂ Male & female
[illegible]



Amazon leaf-fish
*Monocirrhus polyacanthus*



Diamond moonfish
*Monodactylus argenteus*

Body deep and highly compressed

Archerfish
*Toxotes jaculatrix*

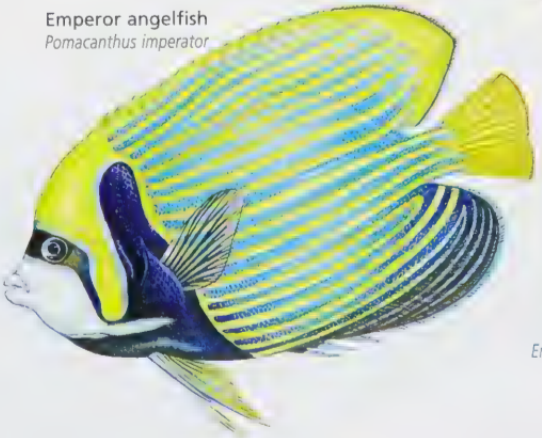
Spotted scat
*Scatophagus argus*

Stripey
*Microcanthus strigatus*

Distinctive oblique black stripes

Threadfin butterflyfish
*Chaetodon auriga*

Prominent black band through eye



Emperor angelfish
*Pomacanthus imperator*

Old wife
*Enoplosus armatus*

## FACT FILE

**Amazon leaf-fish** This species from South America looks and behaves like a floating dead leaf. Colored shades of brown with a twig-like chin barbel, it moves by means of transparent fins, lunging at unsuspecting prey with its enormous mouth

Up to 3 in (7.5 cm)
Up to 1 oz (30 g)
Oviparous, guarder
♀♂ Male & female
Common

N. South America

**Emperor angelfish** As occurs in most angelfishes, juvenile coloration in this species differs strikingly from that of adults. Young fish have incomplete rings of white and blue overlaying a blue-black background but develop light blue and yellow stripes as they mature

Up to 16 in (40 cm)
Up to 3 lb (1.4 kg)
Oviparous
♀♂ Male & female
Common

Indo-Pacific & Red Sea

## TAKING AIM

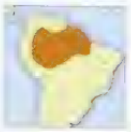
Archerfishes fire water jets from the mouth to knock insects and other prey from overhanging branches. Rapid oral cavity compressions force water through a tube formed by the tongue pressing against the specially grooved palate The archerfish *Toxotes jaculatrix* has a shooting range of about 5 feet (1.5 m) They will also shoot at swarms of flying insects hovering above the surface

## FACT FILE

**Bluestreak cleaner** Pairs or small groups of bluestreak cleaners set up permanent "cleaning stations" near cave entrances and beneath rocky overhangs in tropical reefs throughout the Indo-Pacific. Here they service "clients"—larger fishes looking to be picked free of parasites.

Indo-Pacific & Red Sea

**Freshwater angelfish** Eggs laid onto the submerged leaf of an aquatic plant are guarded and fanned constantly by freshwater angelfish parents for the 3 days until hatching. Fry are gathered into a dense pack each evening for ease of protection



- Up to 3 in (7.5 cm)
- Up to 8 oz (225 g)
- Oviparous, guarder
- ♀♂ Male & female
- Common

N.E. South America

## ORAL NURSERIES

All of the cichlids show some form of parental care, the most advanced being continuous mouth-brooding. Usually the female scoops her eggs up into her mouth quickly after laying them, nuzzles the male near his genital opening, and then draws his ejaculated sperm into her mouth where she may brood embryos and young for more than 3 weeks. Toward the end of that period, the young are released at intervals to forage

Viviparous blenny
*Zoarces viviparus*

Yellowhead jawfish
*Opistognathus aurifrons*

Constructs elaborate burrows; male broods the eggs orally

Greater weever
*Trachinus draco*

Lies buried in sand; spines of the first dorsal fin and gill cover have venom

Atlantic mudskipper
*Periophthalmus barbarus*

Atlantic stargazer
*Uranoscopus scaber*

False cleanerfish
*Aspidontus taeniatus*

Lesser sandeel
*Ammodytes tobianus*

Burrows in sand but also forms huge schools in mid-water

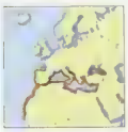
Redtail surgeonfish
*Acanthurus achilles*

Named for the sharp spine or spines they possess on the caudal peduncle

Moorish idol
*Zanclus cornutus*

## FACT FILE

**Atlantic stargazer** A camouflaged bottom-dweller, the Atlantic stargazer has a small, worm-like appendage on its bottom lip that it wriggles to attract prey. Morphological adaptations to a life spent almost completely buried in sandy sediments include having a high-set mouth, nostrils, and eyes. Defenses against predators include a venomous spine behind the operculum and electric organs behind the eyes.

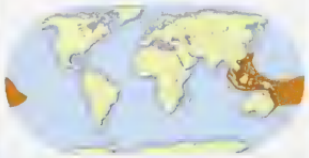


- Up to 16 in (40 cm)
- Up to 33 oz (940 g)
- Oviparous
- ♀♂ Male & female
- Locally common

E. Atlantic; Mediterranean & Black seas

**False cleanerfish** This blenny species mimics the bluestreak cleaner wrasse *Labroides dimidiatus*, which large fishes seek out for the removal of parasites. The two look so alike in their natural habitat that few other fishes seem capable of recognizing the interloping master of disguise. When the false cleaner is approached, however, it nips off pieces of flesh instead.

- Up to 4½ in (11.5 cm)
- Up to 2½ oz (75 g)
- Oviparous
- ♀♂ Male & female
- Locally common



Indo-Pacific

## AMPHIBIOUS FISHES

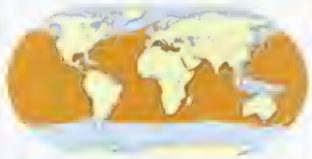
Mudskippers use their muscular tail and pectoral fins to "skip" over mud at low tide and even climb trees with the aid of a pelvic fin "suction cup." There are more than 30 species of mudskipper, found mainly in the muddy, intertidal mangrove forests of Southeast Asia and Africa. They take in oxygen through their moist skin, which is richly endowed with blood vessels.

*Land lovers !*

## FACT FILE

**Swordfish** Adult swordfish lack scales, teeth, and a lateral line. They mostly feed on pelagic fish—taken anywhere from surface waters to depths of about 2,100 feet (650 m)—using their sword to slash prey. This species is the only member of the family Xiphiidae

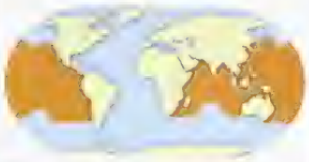
- Up to 16 ft (4.9 m)
- Up to 1,435 lb (650 kg)
- Oviparous
- ♀♂ Male & female
- Data deficient



Worldwide in tropical and temperate seas

**Indo-Pacific sailfish** No other fish is known to swim faster than the sailfish, which has been clocked in excess of 68 mph (110 km/h). It uses its rapier-like beak to stun and maim prey, which it then scoops up with toothless jaws

- Up to 11½ ft (3.5 m)
- Up to 220 lb (100 kg)
- Oviparous
- ♀♂ Male & female
- Common



[illegible]

## CONSERVATION WATCH

**Big decline** The blue marlin is one of the most sought-after gamefishes, but sportfishing is not its biggest threat. Huge numbers are caught and killed accidentally on long-lines set for tuna and swordfish by commercial fishing operations. Being predators at the top of the food chain, they occur at naturally low levels of abundance, making their populations vulnerable to overexploitation of any sort.

The results of a 10-year study by German and Canadian scientists, published in 2003 in the international science journal *Nature*, indicate that blue marlin numbers, along with those of other large fishes in the world's oceans, [illegible]ned dramatically during the [illegible]st half of the 20th century.

Ornate ctenopoma
*Microctenopoma ansorgii*

Siamese fighting fish
*Betta splendens*

Pearl gourami
*Trichogaster leerii*

Gourami
*Osphronemus goramy*

Can breathe moist air and survive long periods out of water

Lips have horn, teeth; filter feeder and grazer on benthic algae

Kissing gourami
*Helostoma temminckii*

Sucking lips used for kissing other fishes, plants and other objects

Brill
*Scophthalmus rhombus*

Climbing perch
*Anabas testudineus*

Zebra sole
*Zebrias zebra*

Distinctive stripes give this sole its common name

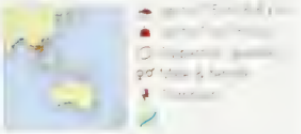
Very large flatfish that is an active predator of other fishes

Atlantic halibut
*Hippoglossus hippoglossus*

Summer flounder
*Paralichthys dentatus*

## FACT FILE

**Siamese fighting fish** [illegible] by blowing bubbles around [illegible] which they then guard aggres[illegible] The male-male fighting for [illegible] species is famous involves threat displays and fin-nipping



**Climbing perch** [illegible] breathing organ [illegible] gills, [illegible] oxygen-depleted environments. When ponds dry up it will "walk," using its fins, in search of water and reportedly even climb low trees

S.E. Asia

**Brill** Like all other flatfishes, this marine species relies extensively on camouflage to hide it from both predators and prey and can change its body color to match the surrounding seabed environment

E. North Atlantic, Mediterranean & Black Sea

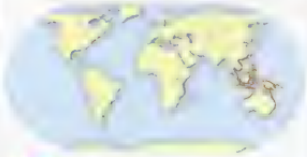
## MIGRATING EYES

Larval flatfishes look like other young fishes to begin with but soon begin leaning sideways as one eye (left in some species, right in others) migrates across to take up position beside the other. Simultaneously, the front of the skull twists to bring the jaws into an oblique sideways position

## FACT FILE

**Harlequin filefish** The presence of this fish, a coral reef specialist, is a sign of environmental health. It lives almost exclusively on coral polyps and is one of the first species to disappear from reefs affected by pollution or global warming.

- Up to 4 in (11.5 cm)
- Up to 3 oz (85 g)
- Viviparous
- Male & female
- Common



Indo-Pacific Reefs

**Guineafowl puffer** This species is typical of pufferfishes in that it is poisonous to eat and has its teeth incorporated into the jawbone to form a parrot-like beak. This enables it to feed mainly on the soft-bodied polyps in the tips of branching coral species.

- Up to 19 in (50 cm)
- Up to 4 lb (1.8 kg)
- Oviparous
- Male & female
- Common

Indo-Pacific, E. Africa to America

**Thornback cowfish** Like their close relatives the boxfishes, cowfishes are enclosed in a protective outer armour. They also have a unique form of locomotion—or rather, form swimming—which involves a sculling motion of the tail fin and no body flexing. This does not provide speed, but allows a very maneuverable hovering.

- Up to 12 in (30 cm)
- Up to 1 lb (0.45 kg)
- Oviparous
- Male & female
- Common

Indo-Pacific, E. Africa

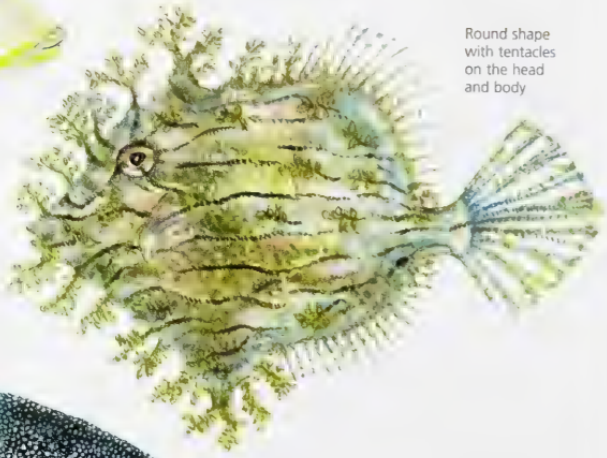
Clown triggerfish
*Balistoides conspicillum*

First dorsal spine can be locked erect by the small second spine; if depressed like a trigger it unlocks the first spine

Blackbar triggerfish
*Rhinecanthus aculeatus*

Sleeps on its side and makes a whirring noise if alarmed

Prickly leatherjacket
*Chaetodermis penicilligerus*

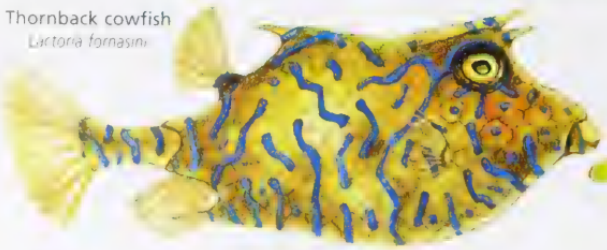


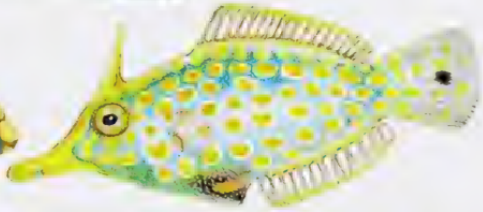
Round shape with tentacles on the head and body

Guineafowl puffer
*Arothron meleagris*

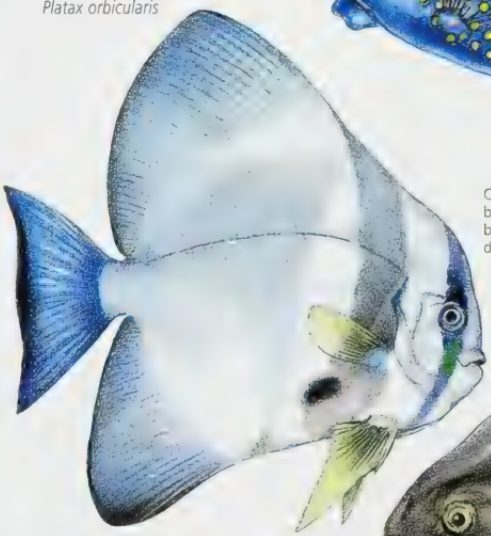
Body of this puffer is covered by prickles

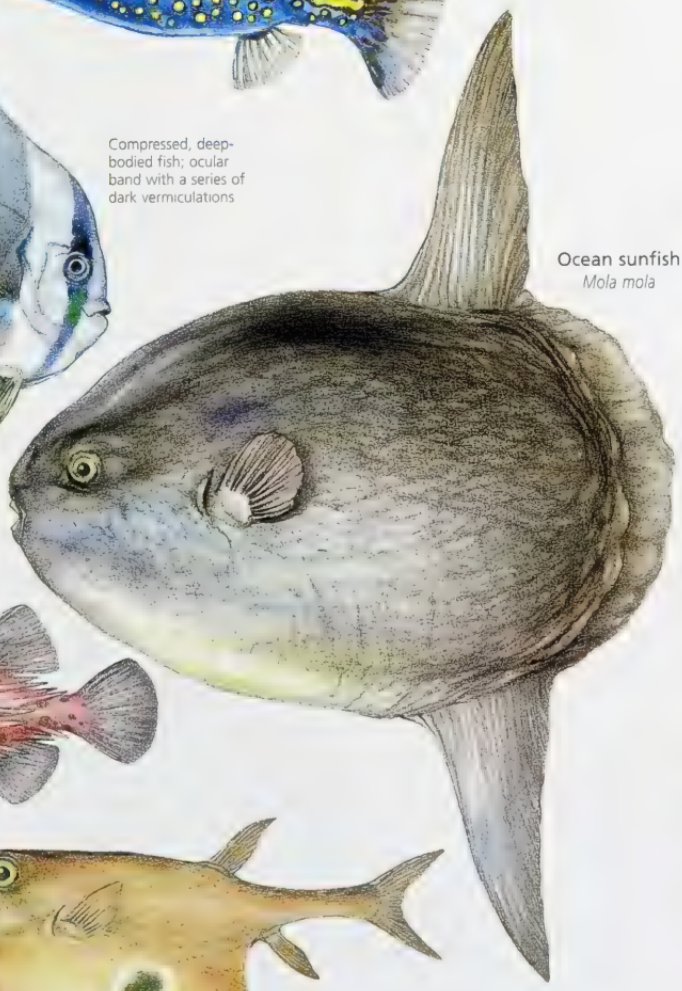
Thornback cowfish
*Lactoria fornasini*

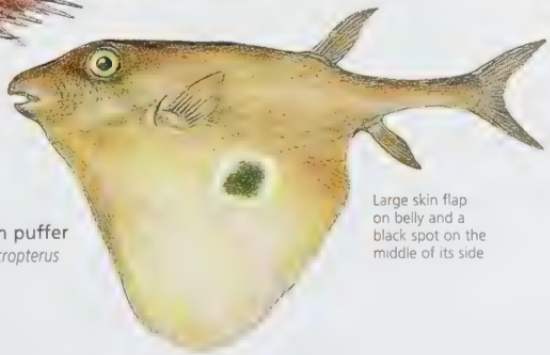




Harlequin filefish
*Oxymonacanthus longirostris*






## FACT FILE

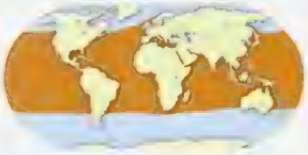
**Freshwater pufferfish** When they are threatened, pufferfishes pump air or water into a distensible stomach sac to greatly increase the size of their bodies and appear more formidable. This also forces spines and scales to protrude, making them harder to swallow

Up to 26½ in (67 cm)
Up to 15 lb (6.8 kg)
Oviparous
♀♂ Male & female
Common

Central Africa

**Ocean sunfish** The disk-shaped body of the sunfishes has an abbreviated appearance at the back end because there is no tail fin. Forward motion is provided instead by sculling with the dorsal and anal fins, which have shifted toward the rear.

Up to 11 ft (3.3 m)
Up to 3,300 lb (1,500 kg)
Oviparous
♀♂ Male & female
Common



Cosmopolitan in warm & temperate oceans

## PUFFERFISH POISON

Some pufferfishes are highly poisonous, particularly those of the Indo-Pacific. Tetrodotoxin, which is found throughout the body but concentrated in the liver, ovaries, and gut, is a powerful nerve poison considerably stronger than cyanide These fishes also release this toxin into the surrounding water when frightened by a potential predator

***Dicey dining*** *The spec[illegible] poison-free flesh of [illegible] spec[illegible] Japan and Korea, even though their organs are imbued with deadly tetrodot[illegible]*

# INVERTEBRATES

# INVERTEBRATES

| INVERTEBRATES |
| --- |
| PHYLA > 30 |
| CLASSES > 90 |
| ORDERS > 370 |
| SPECIES > 1.5 million |

Constituting more than 95 percent of all known animal species, invertebrates are not distinguished by a single positive characteristic. Instead the group is defined by what its members lack: they have no backbone, no bones, and no cartilage. As a term of classification, *invertebrate* is commonly used but has little scientific validity. Unlike vertebrates, which belong to a single phylum, invertebrates are a collection of more than 30 phyla, some of which are more closely related to vertebrates than to each other. Invertebrates encompass such diverse forms as porous sponges, floating jellyfishes, parasitic flatworms, jet-propelled squids, hard-cased crabs, venomous spiders, and fluttering butterflies.

**Inside and outside** An inverted hydrothermal vent, the body of worms and many other invertebrates, but only visible in high concentration in water. An external exoskeleton helps arthropods such as lobsters to survive long.

## SOFT-BODIED CREATURES

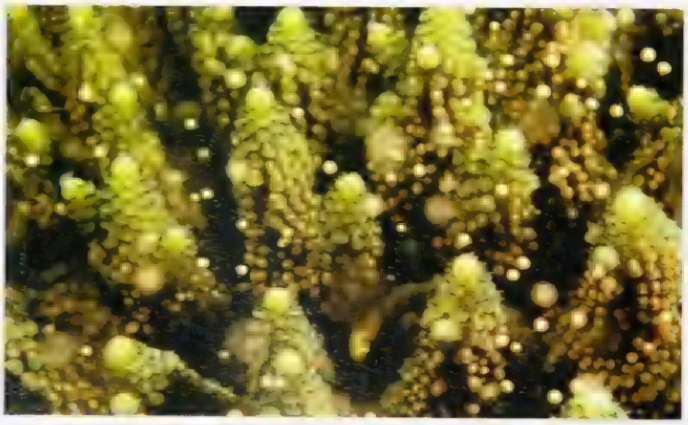
The first animals to evolve were invertebrates, but their soft bodies left no traces. Although tracks and burrows appear in the fossil record about 1 billion years ago, the oldest fossilized animal remains date back to about 600 million years ago, near the end of the Precambrian period. Known as Ediacaran fauna, these include forms that resemble sponges, jellyfishes, soft corals, segmented worms, and echinoderms. Beginning roughly 60 million years later, the Cambrian period is associated with the explosion of invertebrate life. By its conclusion, about 500 million years ago, all of today's invertebrate phyla seem to have appeared.

Although their greatest diversity occurs in the sea, invertebrates are now found in virtually all land and water habitats. Most species are small, and some are microscopic: many rotifers are less than [illegible] inch (0.001 mm) long. However, a few invertebrates reach staggering sizes: the elusive giant squid can be up to 59 feet (18 m) long and weigh up to 1,980 pounds (900 kg).

There are two basic invertebrate body plans. Species with radial symmetry, such as jellyfish and sea anemones, have a circular body plan and a central mouth. Others, such as worms and insects, have bilateral symmetry, with a distinct head and right and left sides.

Invertebrates lack bones, but are supported by some sort of skeleton. While many appear soft, they are held together by protein fibers, a feature of all animals. Many worms have a hydroskeleton, with fluid held under pressure inside the body cavity. Sponges and echinoderms have endoskeletons, with hard elements inside the tissues. Most mollusks and all arthropods have an exoskeleton, a hard, external casing. A mollusk's exoskeleton is a hard shell, while an arthropod's tough exoskeleton is jointed and flexible.

Most invertebrates reproduce sexually, laying vast numbers of fertilized eggs that are usually left to hatch on their own. Some species, however, develop from unfertilized eggs, and others reproduce by fragmenting or budding, with parts of their own body becoming the offspring. Invertebrate young are often quite unlike their parents and must go through metamorphosis to transform into adults.



**External fertilization** [illegible]

**Hunting spider** [illegible]

# INVERTEBRATE CHORDATES

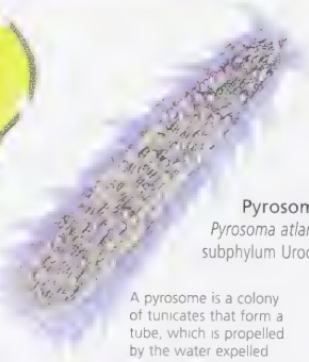
PHYLUM Chordata
SUBPHYLA 2
CLASSES 4
ORDERS 9
FAMILIES 47
SPECIES > 2,000

The phylum Chordata is made up of three subphyla. The largest of these is Vertebrata, which includes all the vertebrates (mammals, birds, reptiles, amphibians, and fishes). The other two subphyla are marine invertebrate groups: Urochordata, which contains about 2,000 species of sea squirts and their relatives, and Cephalochordata, which has about 30 species of lancelets. These invertebrate chordates do not have a backbone made of vertebrae, but they do have a flexible skeletal rod known as a notochord. The notochord is present in vertebrate embryos, but is resorbed and replaced by the backbone. Vertebrates appear to have evolved from invertebrate chordates.

**From the deep** The predatory tunicate (*Megalodicopia hians*) lives on the floor of deep oceans. After a small animal such as a krill floats into its mouth-like hood, the hood quickly closes to capture the prey

**Colonies** This photo shows several colonies of magnificent ascidians (*Botrylloides magnicoecum*). The dark spots represent individual inhalant openings; the sieve-like plates are communal exhalant openings

Ink-pot sea squirt
*Polycarpa aurata*
subphylum Urochordata



Pyrosome
*Pyrosoma atlanticum*,
subphylum Urochordata

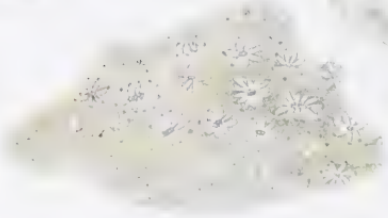
A pyrosome is a colony of tunicates that form a tube, which is propelled by the water expelled as they filter-feed

When a sea squirt suddenly contracts and closes its inhalant opening, a jet of water shoots out of the exhalant opening

Sea potato
*Halocynthia papillosa*,
subphylum Urochordata

Star ascidian
*Botryllus schlosseri*,
subphylum Urochordata

Common lancelet



Lightbulb sea squirt
*Clavelina lepadiformis*
subphylum Urochordata

## FIXED AND FREE

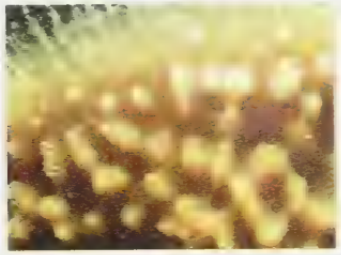
Also known as tunicates, sea squirts hatch from eggs as a tadpole-shaped larva with a notochord in its tail. After dispersing to a new location, the tadpole usually attaches itself to the seafloor, resorbs the tail and notochord, and moves its mouth to its free end. This sessile sea squirt is a bag-like creature. Water enters through an inhalant opening and leaves via an exhalant opening. On the way, the water passes through a perforated pharynx (throat), which uses mucus to filter out particles of food. Sea squirts can be solitary or colonial. Most are fixed as adults, but a small number remain free-living throughout their lives. They are almost all hermaphrodites that release eggs and sperm into the water to produce their young.

Superficially resembling little eels, lancelets (or amphioxus) can swim well, but usually stay partly buried in sand or gravel in shallow waters, with only the head protruding. They filter-feed using the same method as sea squirts, with water entering one opening, passing through the pharnx, and exiting via a second opening. The sexes are separate and the eggs are fertilized externally.

# SPONGES

**PHYLUM** Porifera
**CLASSES** 3
**ORDERS** 18
**FAMILIES** 80
**SPECIES** about 9,000

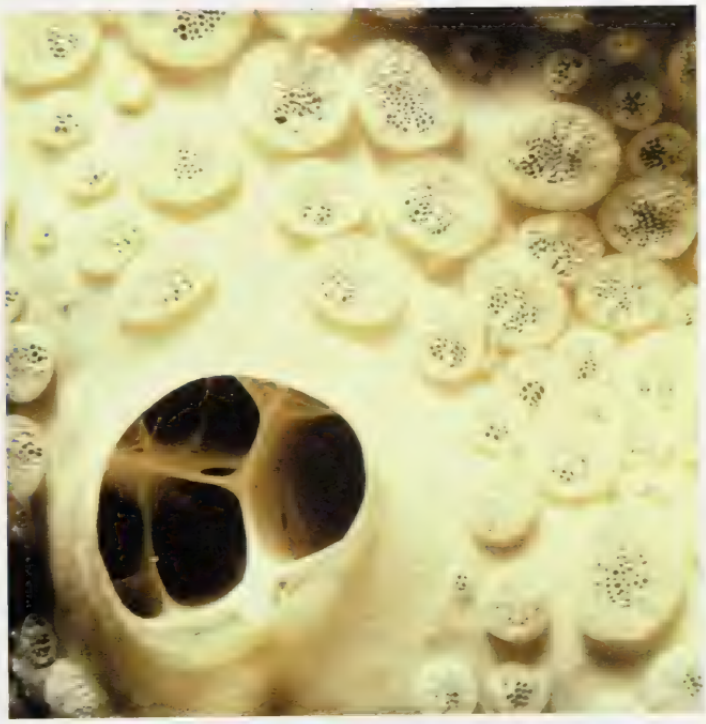
More than 2,000 years ago, Aristotle considered sponges to be animals, but his claim remained without proof until 1765. In the interim, most scientists believed sponges, with their lack of movement and often branching form, to be plants. Sponges are unique in the animal kingdom. They do not possess a nervous system, muscles, or stomach. Their cells do not form tissues or organs, but are specialized for particular functions, such as food collection, digestion, defense, or skeleton formation. Able to migrate throughout a sponge, the cells can transform from one type to another, which allows the sponge to completely regenerate from a fragment or even from individual cells.

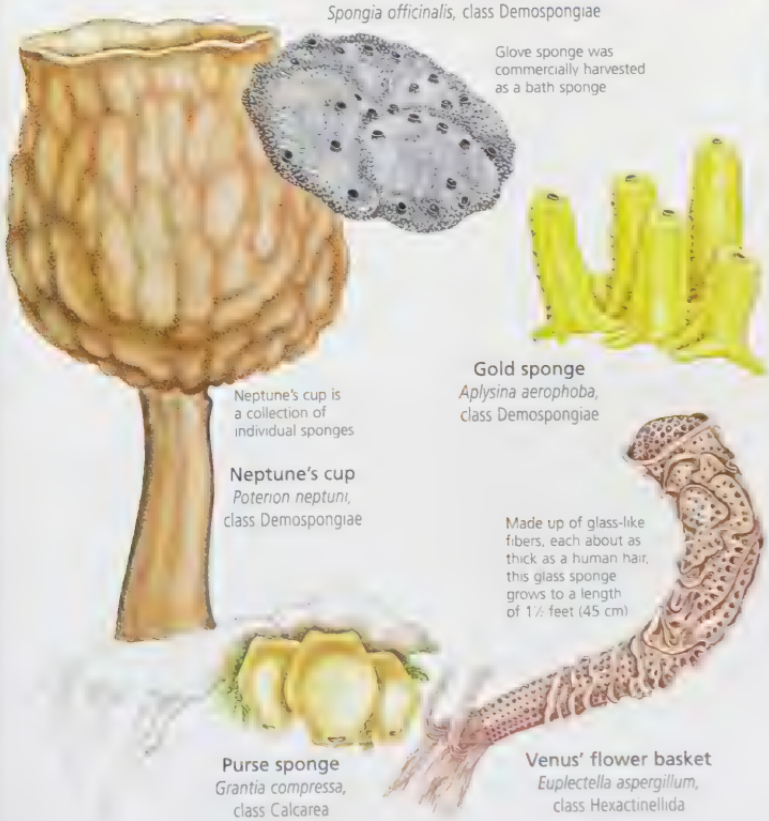


**Electric sponge** Although they lack nerves, glass sponges (class Hexactinellida) react to disturbances by sending electrical impulses through their body, which prompts their food-filtering system to shut down.

**Supportive spicules** A sponge's skeleton is made of units known as spicules, which can be scattered throughout the sponge or combined into fibers. This magnified view shows the needle-like and star-like spicules of a sponge at 100 times their actual size

**Budding young** While most sponges reproduce sexually, many also use asexual reproduction. Some species fragment, while others grow buds (far right), which break away to become new sponges. Sponges may also expel gemmules, collections of cells and food granules. The gemmules can remain in a dormant state, growing into a sponge only when conditions are favorable






## POROUS FILTER-FEEDERS

Ranging in length from less than ½ inch to 6½ feet (1 cm to 2 m), sponges may be shaped like trees, bushes, vases, barrels, balls, cushions, or carpets, or they may simply form a shapeless mass. They are found in every marine habitat, from the shallows to the depths, and a small number of species have colonized freshwater lakes and rivers.

The skeletons of sponges are made of minerals, protein, or both. Species in the class Calcarea have skeletons of calcium carbonate and tend to be small and drab. Those in the class Hexactinellida are known as glass sponges and have skeletons made of silica. More than 90 percent of sponge species belong to the class Demospongiae. They have skeletons of silica and/or protein.

Sponges usually feed by filtering microorganisms from the water. After entering via tiny pores called ostia, the water travels through a system of canals, and is expelled via a large opening called the osculum. The collar cells that line the sponge's interior have tiny whip-like flagella to maintain a constant current. A few carnivorous sponges use hooks like filaments to capture crustaceans.

Most sponges are hermaphrodites. Sperm are released into the water and carried to other sponges to fertilize their eggs. The larvae are free-swimming for a short period before settling down to a sessile adult. Developing from an adult sponge

# CNIDARIANS

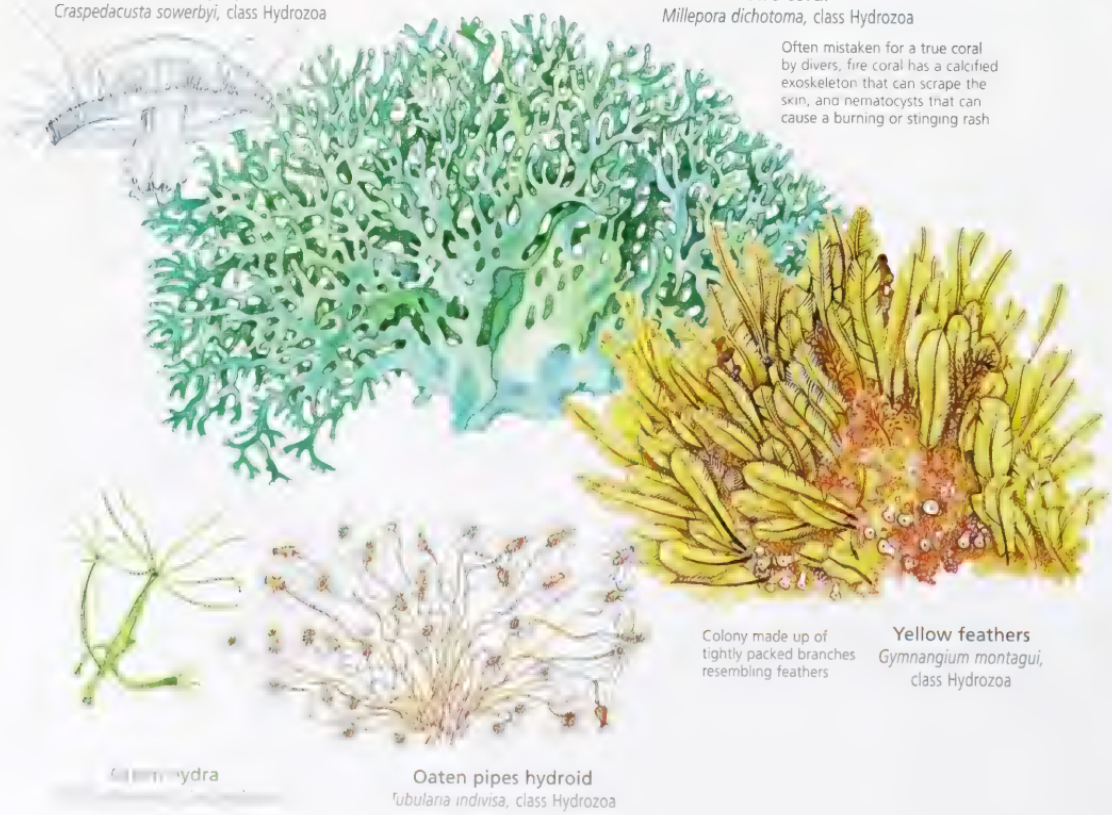
| | |
|---|---|
| PHYLUM | Cnidaria |
| CLASSES | 4 |
| ORDERS | 27 |
| FAMILIES | 236 |
| SPECIES | about 9,000 |

The phylum Cnidaria is a diverse assortment of mostly marine invertebrates, including sea anemones, corals, jellyfishes, and hydroids. All members are carnivores and use cells containing stinging nematocysts to subdue prey and deter predators. The cnidarian body is organized around a gastrovascular cavity that digests food and acts as a hydroskeleton. Food enters and waste leaves via a single opening, the mouth, which is often surrounded by tentacles. Cnidarians occur in two forms: polyp and medusa. Polyps are cylindrical and attached to a surface, with the mouth and tentacles at the free end. Medusae are free-swimming and umbrella-shaped, with the mouth and tentacles hanging down.

**Jelly sandwich** Between a cnidarian's two cell layers, the outer ectoderm and the inner endoderm, there is a jelly-like layer known as the mesoglea (shown as orange). In polyps, the mesoglea is thin, but in medusae, it forms the bulk of the animal.

**Fixed in position** The jewel anemone (*Corynactis viridis*) has up to 100 tentacles arranged in three rings around its mouth. Attached to the substrate by a sucker-like disk, sea anemones rarely move but some are able to glide very slowly.

**Floating home** At up to 1½ feet (45 cm) wide, the purple jellyfish (*Pelagia panopyra*) offers a temporary haven to fish and young crabs. Like other jellyfishes, it has only weak jet propulsion and relies mainly on ocean currents for transport.




## POLYPS AND MEDUSAE

A small number of cnidarians live in fresh water, but most are marine, occupying all latitudes and levels of the ocean and reaching their greatest numbers in shallow tropical waters. They feed primarily on the fishes and crustaceans that swim past. Found mainly on the tentacles, a cnidarian's nematocysts (stingers) hold a coiled, barbed thread that can be ejected to spear and paralyze the prey. The tentacles then move the food to the mouth.

While corals and sea anemones exist only as polyps, many other cnidarians alternate between polyp and medusa during their life-cycle. Usually, the polyps asexually produce medusae, and the medusae sexually produce larvae that become polyps. Polyps and some medusae may grow buds or divide to create more of their own kind asexually. If the offspring detach from the parent they become clones, but if they remain attached they form colonies, such as the vast colonies that make up coral reefs. In some colonies, each member has a particular role and form, and may be specialized for feeding, defense, reproduction, or locomotion, for example.

**Upside-down jellyfish**
*Cassiopeia andromeda*, class Scyphozoa

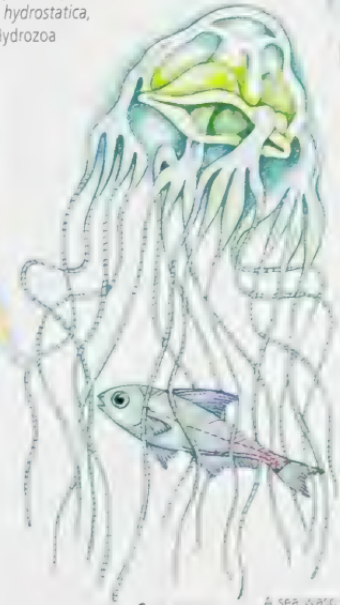
Attaches to sandy ocean floor

**Lion's mane jellyfish**
*Cyanea arctica*, class Scyphozoa

**Portuguese man-of-war**
*Physalia physalis*, class Hydrozoa

The Portuguese man-of-war is a free-floating colony, with a modified medusa forming the gas-filled float, and some polyps delivering a potent sting, some digesting food, and others reproducing

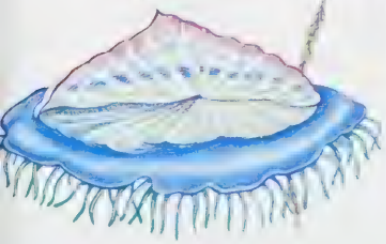
**Hula skirt siphonophore**
*Physophora hydrostatica*, class Hydrozoa



**Sea wasp**
*Chironex fleckeri*, class Cubozoa

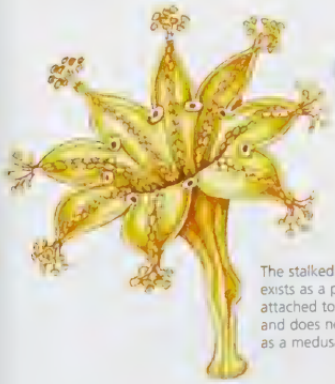
A sea wasp contains enough venom to kill 60 people

**Dead man's fingers**
*Alcyonium digitatum*, class Anthozoa



**By-the-wind sailor**
*Velella velella*, class Hydrozoa

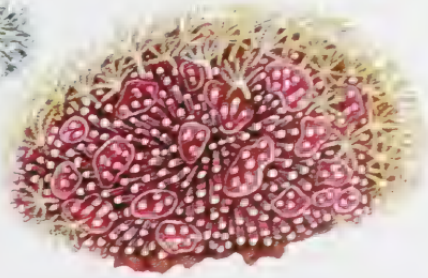
**Phosphorescent sea pen**
*Pennatula phosphorea*
class Anthozoa



The stalked jellyfish exists as a polyp attached to algae and does not occur as a medusa

**Stalked jellyfish**
*Haliclystus auricula*, class Scyphozoa

**Formosan soft coral**
*Sarcophyton glaucum*, class Anthozoa



**Organ-pipe coral**
*Tubipora musica*, class Anthozoa

## FACT FILE

**Class Scyphozoa** [illegible]

Species: [illegible]

**Common jelly**
[illegible]

**Class Hydrozoa** [illegible]

Species: [illegible]

**Freshwater hydra**
[illegible]

**Class Cubozoa** [illegible]

Species: [illegible]

Worldwide, tropical & temperate seas

## YOUNG CNIDARIANS

[illegible]

## FACT FILE

## GREAT BARRIER REEF

## CONSERVATION WATCH

Red brain coral

Cluster finger coral
Porites porites, class Anthozoa

Bubble coral

Black coral

Red coral

Beadlet anemone
Actinia equina
class Anthozoa

West Indian sea fan
Gorgonia flabellum

Mushroom coral

# FLATWORMS

| | |
|---|---|
| PHYLUM | Platyhelminthes |
| CLASSES | 4 |
| ORDERS | 35 |
| FAMILIES | 350 |
| SPECIES | 13,000 |

The flatworms that make up the phylum Platyhelminthes range from microscopic free-living species, to tapeworms up to 100 feet (34 m) long that live inside humans and other vertebrates. The simplest animals possessing bilateral symmetry, flatworms have no body cavity and lack respiratory and circulatory systems. A few parasitic species also do without a digestive system. In most species the gut has a single opening to take in food and expel waste. The tentacled head contains a brain and some of the sense organs, including ocelli (simple eyes) that can perceive light and dark, and receptors that can detect chemicals, balance, gravity, and water movement.

**A long colony** A parasite of fish, the tapeworm Hymenolepis diminuta is shown here at 60 times its actual size and with its rostal armament, sweeping up infective proglottids and the oncoliers all in tow.

## A PARASITIC LIFE

[illegible]

**Eggs in the Chinese liver fluke** [illegible]

**Crawling leaf** Amongst some land planarians (unknown, most flatworms are marine), many species, such as Bipalium pestiferum, are terrestrial.

## DIFFERENT LIFESTYLES

Flatworms are divided into three classes. The first of these, Turbellaria, is predominantly free-living. Most species are marine but some are found in moist soil and water, and a few live even inside living flesh and air spaces. There are over 3,000 species of Turbellaria that live on land in moist habitats. Turbellaria are usually giant sea hermaphrodites. They store sperm from mating, like the bees, in special glands, ready to fertilize eggs as they are laid.

The other two flatworm classes are all parasitic, having a host part of their life cycle. Monogenea are small flukes. As the name implies, they have a monogenetic life cycle, having only one host. Most live on the gills of fish, but some live on the skin or in the eyes. Trematodes, flukes, are hermaphrodites. The adults are found in vertebrates, mainly mammals, in which they live in the gut, liver, lungs, or bloodstream. Many species have complex life cycles involving several hosts, usually including a snail. Parasitic flatworms are responsible for many human diseases, such as schistosomiasis (bilharzia), which affects over 200 million people in the tropics. Many species are also important pests of farm livestock, causing considerable economic losses.

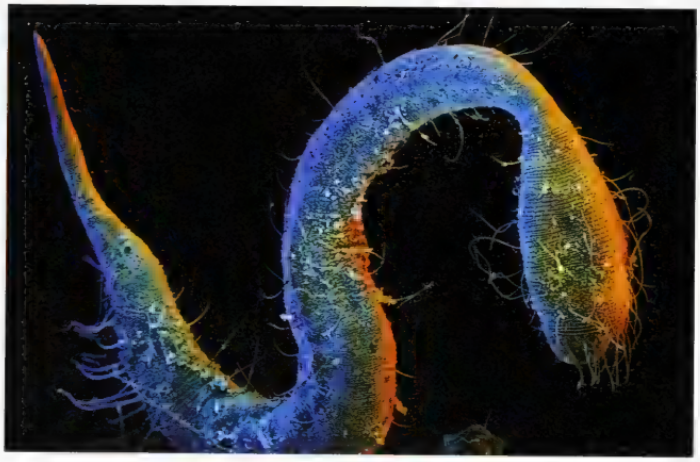
# ROUNDWORMS

PHYLUM Nematoda
CLASSES 4
ORDERS 30
FAMILIES 185
SPECIES > 20,000

Although a species of roundworm that parasitizes sperm whales can grow to a length of 43 feet (13 m), most members of the phylum Nematoda are microscopic. Also known as nematodes, roundworms are among the most abundant of all animals—one rotting apple was found to contain about 90,000 individual roundworms. Free-living roundworms occur in virtually every aquatic and terrestrial habitat, and those living in soil play a crucial role in recycling detritus. Parasitic roundworms are found in most groups of plants and animals. Common roundworms, hookworms, pinworms, threadworms, and other roundworms infest more than half the world's human population.

**Uncomplicated design** The simple body plan of a roundworm, shown here in a magnified cross section, is not necessarily a sign of primitiveness, as it may have been derived from a more complex ancestor

**Growing up** After hatching, this juvenile parasitic roundworm possesses all the features of an adult except for a mature reproductive system. It will molt four times before reaching adulthood.



**Adaptable worms** Free-living roundworms may be marine, light, freshwater or terrestrial. Species occur in deep hot springs and even in acidic, salty vinegar.

## SIMPLE AND RESILIENT

Roundworms have long, slender, cylindrical bodies and often resemble tiny threads, a shape that allows them to live in tiny spaces between grains of soil, for example. They are bilaterally symmetrical and often tapered at both ends. The epidermis (skin) secretes a tough but flexible outer cuticle. As in arthropods such as insects, roundworms must molt as they grow. Most shed the cuticle four times before reaching maturity.

When a roundworm moves, it may appear to be thrashing aimlessly back and forth. Between the gut and the body wall, a body cavity known as a pseudocoel contains fluid under pressure. As the worm contracts its muscles, which run only lengthwise down its body, this pressure causes the body to flex from side to side—a method of locomotion that works well against soil particles or in water films.

After food enters a roundworm's mouth, it is pumped through the simple gut by a muscular pharynx (throat). Waste is released through an anus at the rear of the worm.

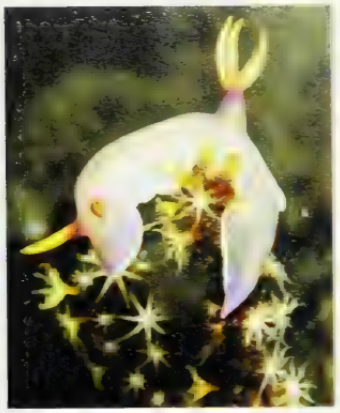
If they encounter unfavorable conditions, such as extreme heat or cold or drought, roundworms can enter a death-like state, known cryptobiosis, for months or even years. When conditions improve, they resume their life processes.

Although some roundworms are hermaphrodites, the sexes are more often separate. During copulation, the male holds onto the female with his hooked rear end. The young resemble miniature adults.

# MOLLUSKS

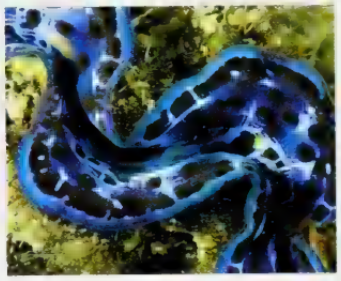
**PHYLUM** Mollusca
**CLASSES** 7
**ORDERS** 35
**FAMILIES** 232
**SPECIES** 75,000

Abundant and adaptable, mollusks have diversified to fill most ecological niches. They are predominantly marine and are found in every level of the ocean, but have also colonized fresh water and land throughout the world. The diversity of their habitats is reflected in an immense variety of forms, from jet-propelled squid to creeping snails and fixed clams. Features shared by most mollusks include a well-developed head; a body cavity containing the internal organs; a specialized skin called the mantle that covers the body and secretes a shell of calcium carbonate; an intucking of the mantle to form a mantle cavity that houses the gills; and a muscular, often mucus-secreting foot.



**Bottom-dweller** Also known as sea slugs, nudibranchs are the less gastropods with external, feathery gills. *Chromodoris bullocki* is shown here feeding on coral.

**Giants of the sea** While many mollusks are small or even minute, some species reach great sizes. The largest bivalve, the giant clam (below), can measure almost 5 feet (1.5 m) across. It is dwarfed, however, by the giant squid, which grows to the astounding length of 59 feet (18 m).



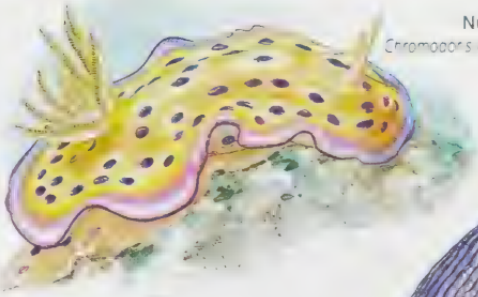
**Changing display** Many cephalopods can change their colors and patterns not for camouflage but also for communication in a ritualized competition. Male Caribbean reef squid, *Sepioteuthis sepioidea*, flash a zebra display to win the rights to a mate.

## VARIED DESIGN

Mollusks are split into eight classes. The Aplacophora is a small class of worm-like mollusks that lack a shell. About 20 species that possess a low, rounded shell constitute the Monoplacophora. The chitons of Polyplacophora are protected by eight plates and creep on a sucker-like foot. Scaphopoda contains the burrowing tusk shells. The clams, oysters, mussels, and other bivalves of the class Bivalvia have a hinged, two-part shell and a tiny head. Gastropods such as snails and slugs (Gastropoda) sometimes have a spiral shell, but many have no shell at all. Octopuses, squids, and other cephalopods (Cephalopoda) have mobile arms and often lack a shell. They include the largest and most intelligent of all invertebrates.

Feeding habits among mollusks are varied. Species may feed on detritus, scrape algae from rocks, eat leaves, filter tiny organisms from the water, or actively pursue prey such as crustaceans and fishes. Food is taken in through the mouth, often with the help of a rasping, toothed organ called a radula, then passes through a complete digestive system terminating at an anus.

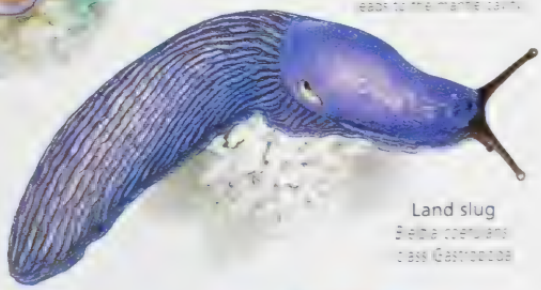
Most mollusks have separate sexes, some release eggs and sperm into the [illegible] Larvae hatch to be free-swimming.



Nudibranch
*Chromodoris kuniei*, class Gastropoda

Raises and lowers mantle as it crawls across the seafloor to highlight its warning coloration

Land slugs breathe air through an opening just behind the head that leads to the mantle cavity.



Land slug
*Bielba coerulans*, class Gastropoda

Atlantic thorny oyster
*Spondylus americanus*, class Bivalvia

Mediterranean bonnet
*Phalium granulatum undulatum*, class Gastropoda

## FACT FILE

**Class Monoplacophora** Known only from fossil shells until 1952, this rare class is made up of small, limpet-like [illegible] living at great depths, from [illegible] feet (200 m) to ocean [illegible] at 23,000 feet (7,000 m). They are distinguished by the repetition of body parts: there are five or six pairs of gills, six pairs of kidneys, and eight pairs of retractor muscles.

Species 31

[illegible]

***Deep crawler*** [illegible]

**Class Polyplacophora** Ranging from [illegible]nch to 16 inches (3 mm to 40 cm) in length, the chitons in this class are long and flat and have a shell of eight overlapping plates. They creep slowly on their broad, flat foot, often using their long radula to scrape algae from rocks or shells. If disturbed, they will clamp down to create a vacuum that makes them very difficult to dislodge.

Species 500

[illegible]

Worldwide, intertidal zone to deeper seafloor

***Shell clinger*** As in other [illegible]

**Class Scaphopoda** [illegible]

[illegible]

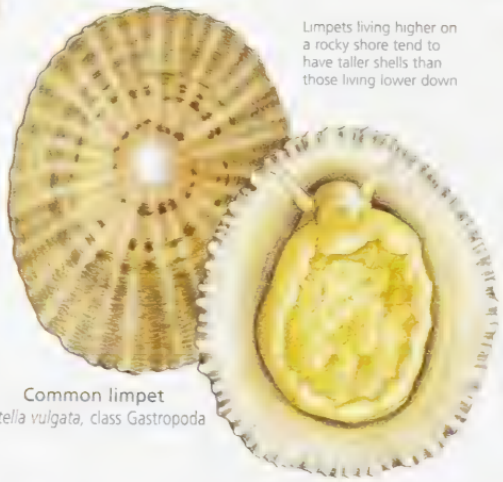
***Burrowing foot*** [illegible]

Glistenworm
*Chaetoderma canadense*, class Aplacophora

Mottled red chiton
*Tonicella marmorea*, class Polyplacophora

Browses on sedentary invertebrates such as sponges and bryozoans

*Stenochiton longicymba*, class Polyplacophora



Limpets living higher on a rocky shore tend to have taller shells than those living lower down

Common limpet
*Patella vulgata*, class Gastropoda

*Chiton olivaceus*, class Polyplacophora

Formosan tusk
*Pictodentalium formosum*, class Scaphopoda

*Neopilina galatheae*, class Monoplacophora

West Indian green chiton
*Criton tuberculatus*, class Polyplacophora

One of the most common chitons in the Caribbean

Elephant tusk
*Dentalium elephantinum*, class Scaphopoda

Unlike the jade-green *Dentalium elephantinum*, most tusk shells are white or yellowish

*Antalis tarentinum*, class Scaphopoda

Tusk shells range from 7/8 inch to 6 inches (4 mm to 15 cm) in length

Spiny cockle
*Acanthocardia aculeata*, class Bivalvia

Corrugations strengthen cockle shell

Common piddock
*Pholas dactylus*, class Bivalvia

Bores into soft rock, clay, and peat

About 4 inches (10 cm) in length and burrows up to 20 inches (50 cm) into the sand

Sand gaper
*Mya arenaria*, class Bivalvia

Burrows in sand, mud, or gravel

Grooved razor clam
*Solen vagina*, class Bivalvia

The pen shell can reach more than 3¼ feet (1 m) in length

Pen shell
*Pinna nobilis*, class Bivalvia

Nut shell
*Nucula nucleus*, class Bivalvia

Flat oyster
*Ostrea edulis*, class Bivalvia

Common mussel
*Mytilus edulis*, class Bivalvia

Shape, size, and color of common mussel's shell vary according to the local conditions

Watering-pot shells secrete a calcareous tube

Greatly reduced valves have fused with tube

Watering-pot shell
*Penicillus javanus*, class Bivalvia

File clam
*Lima hians*, class Bivalvia

Edge of mantle bears many small tentacles

Swan mussel
*Anodonta cygnaea*, class Bivalvia

Freshwater pearl mussel
*Margaritana margaritifera*, class Bivalvia

## FACT FILE

**Class Bivalvia** Clams, oysters, mussels, and other bivalves live inside a hinged two-valve shell. Most are burrowers, but some cement one valve to a firm surface or attach themselves with a byssus, sticky fibers secreted by the foot. Other bivalves live free on the sediment or in the water, or parasitize other aquatic animals

Species 10,000

Worldwide

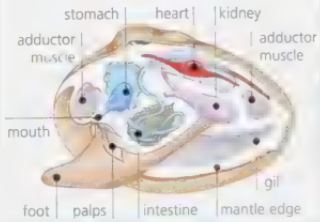
***Brooder*** *The greater European pea clam (Pisidium amnicum) broods its eggs inside its shell and releases young that resemble miniature adults*

## GIANT CLAM

The largest bivalve of all lives on the tropical coral reefs of the Indian and Pacific oceans. Weighing up to 700 pounds (320 kg), giant clams (*Tridacna gigas*) remain embedded in the sediment, filtering plankton from the water. The bulk of their nutrition, however, comes from the algae that they host in the exposed thick lips of the mantle

## INSIDE A BIVALVE

A bivalve's mantle forms a sheet of tissue lining the two valves. The adductor muscles are used to close the shell, and the blade-like foot is often used for burrowing. Bivalves use their gills to filter particles from the water and their palps to sort them by size




## CONSERVATION WATCH

**Unwelcome mussels** First noticed in the Great Lakes in the 1980s, the European zebra mussels (*Dreissena* sp.) have now invaded many of the United States' major rivers and lakes. By filtering vast amounts of phytoplankton from the water, they are having a dramatic effect on aquatic food webs and endangering native mollusks and other species.

## FACT FILE

**Class Gastropoda** This is the largest class of molluscs and includes snails, slugs, limpets, and sea hares. Some gastropods have lost their shell, but most have a spiral shell that is partly hidden from view. Gastropods usually have a distinct head with eyes and tentacles. The marine snails live over the head, allowing the head to retract with the shell. The muscular foot is used for locomotion, burrowing, or holding on.

Species: 80,000

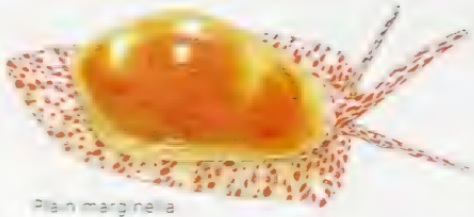
**Gastropod sensitivity** The common tulip Fasciolaria tulipa can sense approaching predators and take evasive action to escape.

## RADULAS

A mollusk's mouth usually includes a tongue-like structure known as a radula, or rasping organ, which is used to scrape food into the mouth. Gastropods use the radula for feeding, mating, and burrowing. Hardened teeth make the radula a tool able to cleave algae from stalks of kelp, pierce the big shell of a clam, or drill through the shell of a snail. Gastropods also use the radula in their defensive behavior, using it to cut through tissue, such as some plants, fungi, etc., and as the feeder of the gastrointestinal tract.

## THE GASTROPOD SHELL

Since gastropods show a very marked variety in their details, the typical shell is a conical cone. The marine snail has evolved to the more complex form, including 2 to 4 whole turns.

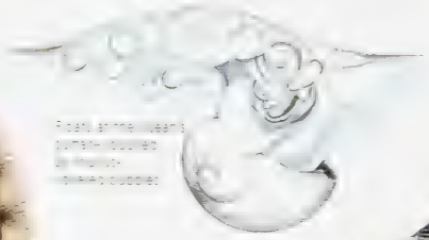


Plain marginella
*Marginella glabrata*
class Gastropoda

*Phyllidia ocellata*,
class Gastropoda

Color of *Phyllidia ocellata* is variable, but it can be identified by its knobby tubercles and white-ringed black spots

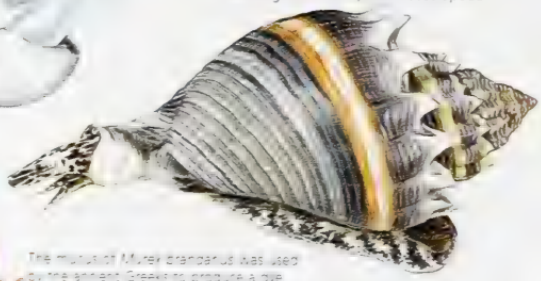
Purple bubble-raft snail
*Janthina janthina*, class Gastropoda



Raft of the queen's purple bubble, protected by mucus-coated bubbles

European edible abalone
*Haliotis tuberculata*
class Gastropoda

Crown conch
*Melongena corona*, class Gastropoda



The mucus of *Murex brandaris* was used by the ancient Greeks to produce a dye called Tyrian purple, which was so rare that it was used only for the clothes of royalty.

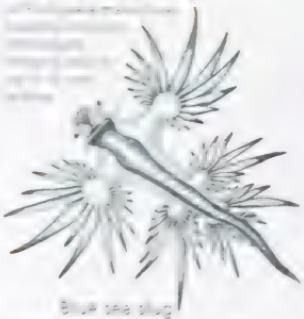
Purple-dye murex
*Murex brandaris*, class Gastropoda

Trumpet triton
*Charonia tritonis*
class Gastropoda

Purplish frills of tissue (branchial feather) attract feeds

Lettuce sea slug
*Elysia crispata*
class Gastropoda

Tiger cowry
*Cypraea tigris*, class Gastropoda



Blue sea slug
*Glaucus atlanticus*, class Gastropoda

Common egg cowrie
*Ovula ovum*, class Gastropoda

Queen conch
*Strombus gigas*, class Gastropoda

Chocolate arion
*Arion rufus*, class Gastropoda

Gray garden slug
*Deroceras reticulatum*
class Gastropoda

Tree slug
*Lehmania marginata*,
class Gastropoda

Eared pond snail
*Lymnaea auricularia*, class Gastropoda

The eared pond snail lives in overgrown stagnant waters

Wormslug
*Boettgerilla pallens*, class Gastropoda

Daudebardia rufa
class Gastropoda

River limpet
*Anclus fluviatilis*, class Gastropoda

Manus Island tree snail
*Papustyla pulcherrima*,
class Gastropoda

White-lipped garden snail
*Cepaea hortensis*, class Gastropoda

The giant tiger snail can grow to 1 foot (30 cm) in length, making it one of the largest snails

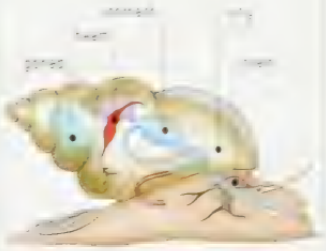
Giant tiger snail
*Achatina achatina*,
class Gastropoda

Escargot
*Helix pomatia*
class Gastropoda

The escargot has been eaten by humans since prehistoric times

## LIFE ON LAND

Several times, during the course of evolution, gastropods have adapted to life on land. There are now roughly 20,000 land snail species, in every one have been lost and replaced by a lung. Some species, however, have both a gill chamber and a lung. Out of water, the shell has become lightweight and now protects against dessication as well as against predators. The mantle and the mucus that cover the body also help to keep the snail moist. If conditions become too dry, a snail will attach itself to a plant or other surface and become dormant. Land slugs cannot have lost the shell, we begin in reserve.




**Air breather** Both land and marine gas, instead the mantle wall has become thin with blood vessels and acts as a lung.

## MATING HERMAPHRODITES

Land snails are hermaphrodites but do not self-fertilize. Before mating, two snails will usually circle each other, touch tentacles, intertwine bodies, and fire each other. In the copulation that follows, sperm are exchanged so that the eggs of both snails can be fertilized.

**Love darts** The courting snails fire darts at their mates. In some cases the darts are intertwined, and all sperm is transferred from the dart to the mate. The dart appears to carry a chemical that helps the sperm reach the storage area in the female reproductive tract.

## CONSERVATION WATCH

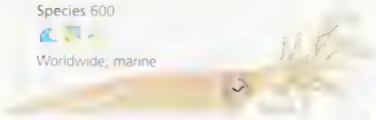
**Mollusk losses** Non-marine mollusks appear to be the most threatened of all animal groups. In the last 300 years, 284 species of non-marine mollusk are known to have become extinct, far more than for mammals (74 extinctions) or birds (129 extinctions). Although the oceans are by no means unpolluted, terrestrial and freshwater habitats have been growing increasingly hostile to human activities, and many mollusk populations have suffered as a result.

## FACT FILE

**Class Cephalopoda** The cephalopod foot lies close to the head and has been modified to form arms, tentacles, and a funnel. Nautiluses retain a large external shell; in squids and cuttlefishes the shell has been reduced and covered by tissue; and octopuses have lost their shell altogether. With the most developed brains of any invertebrates, cephalopods display complex behavior and are able to learn.

Species 600

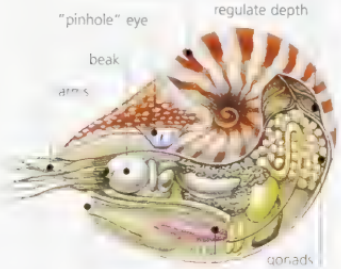
Worldwide; marine



***Predator*** *Like all cephalopods, the European common squid (Loligo subulata) is carnivorous. It captures prey with its tentacles and arms and breaks it up with its beak and radula.*

## THE CHAMBERED NAUTILUS

The most primitive of the cephalopods, chambered nautiluses live in the last chamber of their large shell. The other chambers are filled with gas, and the nautilus controls its buoyancy by adding fluid to or removing fluid from them.




## CEPHALOPOD SIGHT

Most cephalopods have excellent vision. Like the eyes of vertebrates, their eyes have a cornea, iris, lens, and retina. While humans bring objects into focus by changing the shape of the lens, cephalopods move the entire lens closer to or farther from the retina. Guided by the cephalopod's statocysts (balance organs), the slit-shaped pupils maintain a horizontal position no matter what the angle of the head.

All squids have eight arms and two long tentacles, all with suckers

**Long-finned squid**
*Loligo vulgaris*, class Cephalopoda

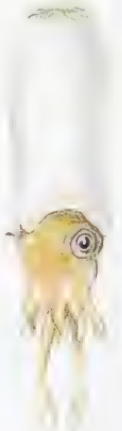
Like many cephalopods, cuttlefishes react to danger by immediately changing color to camouflage themselves, and may also squirt a black ink called sepia to confuse a predator

**Common cuttlefish**
*Sepia officinalis*, class Cephalopoda

To escape predators, flying squids can shoot out of the water and glide for a distance

**Flying squid**
*Ommastrephes sagittatus*, class Cephalopoda

The ram's horn squid is the only surviving member of the family Spirulidae



The internal shell, or pen, of the ram's horn squid acts as a buoyancy device

**Ram's horn squid**
*Spirula spirula*, class Cephalopoda

**Lesser cuttlefish (dwarf bobtail)**
*Sepiola rondeleti*, class Cephalopoda

Chambered nautiluses have about 90 sticky tentacles without suckers

**Common nautilus**
*Nautilus pompilius*, class Cephalopoda

*Abraliopsis morisii*, class Cephalopoda

Has light-producing organs at the tip of its two tentacles and on the underside of its body

Telescope octopus
*Amphitretus pelagicus*, class Cephalopoda

*Lycoteuthis diadema*, class Cephalopoda

Musky octopus
*Eledone moschata*, class Cephalopoda

Blind octopus
*Cirrothauma murrayi*, class Cephalopoda

The paper nautilus is an octopus; the female secretes a fragile bivalve-like case in which to brood her eggs

Octopuses have eight suckered arms but no tentacles

Although never studied alive, the giant squid is thought to reach 59 feet (18 m) in length and weigh up to 1,980 pounds (900 kg), making it easily the world's largest invertebrate

Giant squid
*Architeuthis dux*, class Cephalopoda

Paper nautilus
*Argonauta argo*, class Cephalopoda

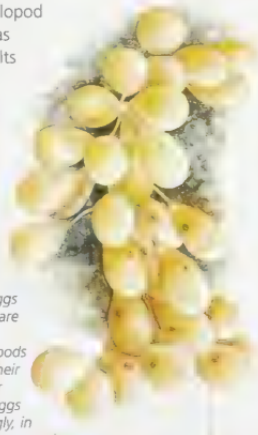
Common octopus
*Octopus vulgaris*, class Cephalopoda

Deep-sea vampire squid
*Vampyroteuthis infernalis*, class Cephalopoda

Long-armed squid
*Chiroteuthis veranyi*, class Cephalopoda

## REPRODUCING CEPHALOPODS

To attract a mate, a male cephalopod will perform some form of courtship. Some cuttlefish and squid species, for example, display a particular pattern on their body to impress females and deter rival males. A male cephalopod delivers his sperm in packages called spermatophores. He transfers these into the female's mantle cavity during copulation using a modified arm known as a hectocotylus. In the tiny male paper nautilus, which is much smaller than the female, the hectocotylus breaks away from his body and crawls into the female. Male cephalopods usually die soon after mating, and females die after they have deposited their eggs. In contrast, chambered nautiluses can breed a number of times and live for much longer. Cephalopod young hatch as miniature adults without a larval stage.



***Egg laying***
*Although the eggs of some squids are free-floating, female cephalopods usually attach their eggs to rocks or seaweed. The eggs may be laid singly, in bunches like grapes, or in clusters protected by a hardened gelatinous covering. The female paper nautilus broods her eggs in a secreted case that she carries with her, and female octopuses stay with their deposited eggs to ventilate them.*

## JET PROPULSION

Most cephalopods swim by expelling jets of water from the mantle cavity through the funnel. The highly mobile funnel can be pointed forward or backward, allowing the cephalopod to swim in either direction. Combined with their streamlined shape, this jet propulsion allows squids to attain speeds of up to 25 miles per hour (40 km/h).

Cuttlefishes are not as fast, but are still agile swimmers. Chambered nautiluses swim using a weaker form of jet propulsion. Although octopuses can squirt water jets, they are bottom-dwellers and more often crawl over rocks using their arms. Deep-water octopuses pulsate their webbed arms to swim like jellyfishes

# SEGMENTED WORMS

PHYLUM Annelida
CLASSES 3
ORDERS 41
FAMILIES 130
SPECIES 12,000

Also known as annelids, segmented worms have a head and a long body made up of segments that look like rings from the outside. Each segment has its own fluid-filled body cavity that acts as a hydroskeleton and contains a separate set of excretory, locomotory, and respiratory organs. The segments are united, however, by common digestive, circulatory, and nervous systems. Segmented worms crawl or swim by wriggling from side to side, or burrow by waves of contractions that pass down the length of the body. Stiff bristles known as chetae protrude from each segment and provide traction. While many species are highly active, others live in burrows or tubes.

**In the soil** Long and thin with a small head earthworms are shaped for burrowing. With up to 650 individuals per square yard (800 per sq. m), earthworms play a crucial role in aerating and fertilizing the soil.

**Food-filtering fans**

## IN WATER AND ON LAND

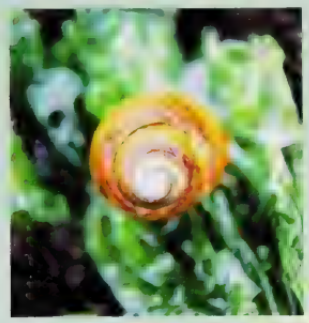
Segmented worms are found in all levels of the ocean, in freshwater lakes and rivers, and on land. They include filter-feeders, predators, and blood-suckers, as well as deposit-feeders such as earthworms, which eat sediment to extract nutrients.

Commonly called bristleworms, the species in the class Polychaeta are almost entirely marine and usually swim or crawl using paddle-like appendages known as parapodia. The parapodia are often lost in tube-living forms, which have a modified head region for food-gathering. Typically, the sexes are separate and release eggs and sperm into the water for fertilization.

The class Clitellata includes many terrestrial and freshwater species such as earthworms and leeches, as well as some marine species. Most are hermaphrodites that exchange sperm by copulation. They all bear a clitellum, a ring of glandular skin that secretes a cocoon for the eggs.

# METAMORPHOSIS

**Veliger larva** Marine gastropods such as sea snails have a free-swimming veliger larva, which feeds and propels itself using tiny hairs known as cilia. The larva gradually develops a shell, mantle cavity, and foot (above), then metamorphoses into an adult (below).



While some newly hatched invertebrates resemble little adults, most look quite distinct from their parents and have a very different lifestyle. To become adults, these young must go through a transformation known as metamorphosis. Corals, clams, many crustaceans, and most other invertebrates metamorphose into adults after a brief larval stage. For most insects, the larval stage is prolonged. In some insect groups, such as crickets and bugs, metamorphosis is incomplete. The hatched form, called a nymph, is structured like the adult, but lacks wings and full sex organs until it emerges from the final molt. Other insects, such as butterflies and bees, have complete metamorphosis. The young, called larvae, differ so much from their parents that they must go through a pupal stage, in which their bodies break down and are built up again as adults.

**Zoea larva** Decapods (such as crabs and lobsters) often hatch as a zoea, a free-swimming larval form (above). The zoea metamorphoses into a postlarva, megalopa (with adult appendages). This sinks to the seafloor and becomes a bottom-dwelling adult (below).

**Egg to nymph to adult** A dragonfly develops through incomplete metamorphosis **1.** Male and female mate. **2.** Female lays eggs in water or in stem of water plant **3.** Aquatic nymph hatches. **4.** Nymph feeds on tadpoles and worms and grows through a series of molts. **5.** Nymph emerges from the water for its final molt. **6.** Adult bursts from the nymphal skin. **7.** Adult rests while its wings dry out. **8.** Feeding on flying insects, adult flies to a new location to find a mate.

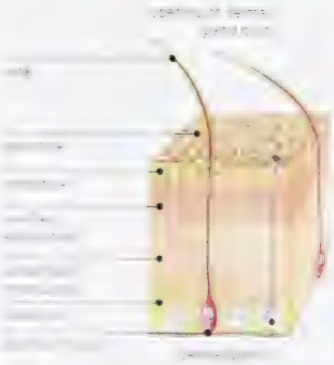
# ARTHROPODS

| | |
|---|---|
| PHYLUM | Arthropoda |
| CLASSES | 22 |
| ORDERS | 110 |
| FAMILIES | 2,120 |
| SPECIES | > 1.1 million |

The insects, spiders, crustaceans, centipedes, and other invertebrates in the phylum Arthropoda account for three-quarters of all known animal species, and millions more remain to be discovered. Arthropods have adapted to fill virtually every ecological niche on land, in fresh water, and in the oceans. Consequently, their anatomy and lifestyles are extraordinarily diverse, but they share a number of defining features. The name arthropod means "jointed feet," and arthropods do have jointed appendages and segmented bodies. They are distinguished from other invertebrates by their tough but flexible exoskeleton, which provides both protection and support.

**Fossilized marine class** Arthropods called trilobites dominate marine fossil beds from about 500 million years ago, and include more than 15,000 known species. They disappeared about 250 million years ago.

**Insects everywhere** Insects account for about 90 percent of all arthropod species. Ubiquitous on land and in fresh water, but rare in the ocean, insects include predators such as the praying mantis, and nectar-feeders such as the swallowtail butterfly.



**Arthropod armor** In relation to arthropod size, the principal [illegible] are of long and slender, made up of a series of hollow rings, [illegible] of which [illegible] Because of the [illegible] the [illegible] [illegible] [illegible]

**Legs and bodies** Tarantulas, ticks, and other spiders have eight legs and a body divided into two parts: the cephalothorax (fused head and thorax) and the abdomen. Insects have six legs and a three-part body made up of a head, thorax, and abdomen.

**Deadly bites** While some arthropods are venomous, few deliver a bite that is fatal to humans. Far more deadly are the diseases transmitted by blood-sucking arthropods such as mosquitoes (below), which transfer malaria and other illnesses from one vertebrate host to another.

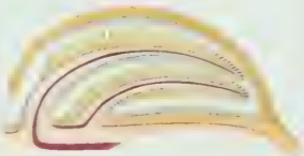
**Limbs in motion** By modifying their jointed limbs for walking, running, leaping, pushing, burrowing, and swimming, arthropods have been able to occupy diverse habitats. In some, such as grasshoppers (right), the legs also hold their hearing organs.

While many arthropods are themselves predators, almost all are prey to vertebrates or to other invertebrates. The compound eyes found on many arthropod species are made up of multiple lenses and are extremely effective at detecting motion. Simple eyes, with a single lens, detect light intensity. Hairs (known as setae), projections, and slits on the antennae, mouthparts, and legs detect subtle vibrations. A cerebral ganglion (brain) connects via a nerve cord to ganglia (clusters of nerve cells) in each body segment. In arthropods' open circulatory system, a heart pumps hemolymph (blood) to bathe the organs.

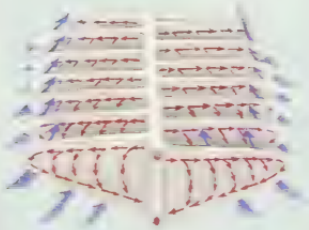
The sexes are separate in most arthropod species, and reproduction usually involves the male's sperm fertilizing the female's eggs. Often, the sperm is transferred in packages known as spermatophores, which the female can use when she is ready. The life stages of arthropods vary greatly. Some species are like small adults when they hatch, while others add segments as they grow. Many insect larvae look nothing like their parents and must go through a pupal stage to transform into a winged adult.

## WAYS OF BREATHING

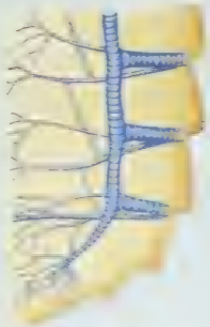
The arthropod exoskeleton offers great protection, but it is also usually too impermeable to allow gas exchange. While some tiny arthropods can breathe directly through the body wall, most have developed specialized structures. Aquatic arthropods tend to have gills. Derived from gills are book lungs, found in many arachnids. Terrestrial arthropods often rely on minute air ducts known as tracheae, which deliver air to all parts of the body.



***Gills*** Gills absorb oxygen from water and help to maintain the animal's salt balance. In crustaceans, the gills are external and often positioned on the legs, but are protected by the exoskeleton. Horseshoe crabs have unique structures called book gills, with flaps like the pages of a book.



***Book lungs*** Mostly derived from the book gills found on horseshoe crabs, book lungs are found primarily arachnids. While blood circulates within the hollow tentacles of a book lung, air circulates through the space between the plates. Arachnids often combine book lungs with tracheae.



***Tracheae*** [illegible]

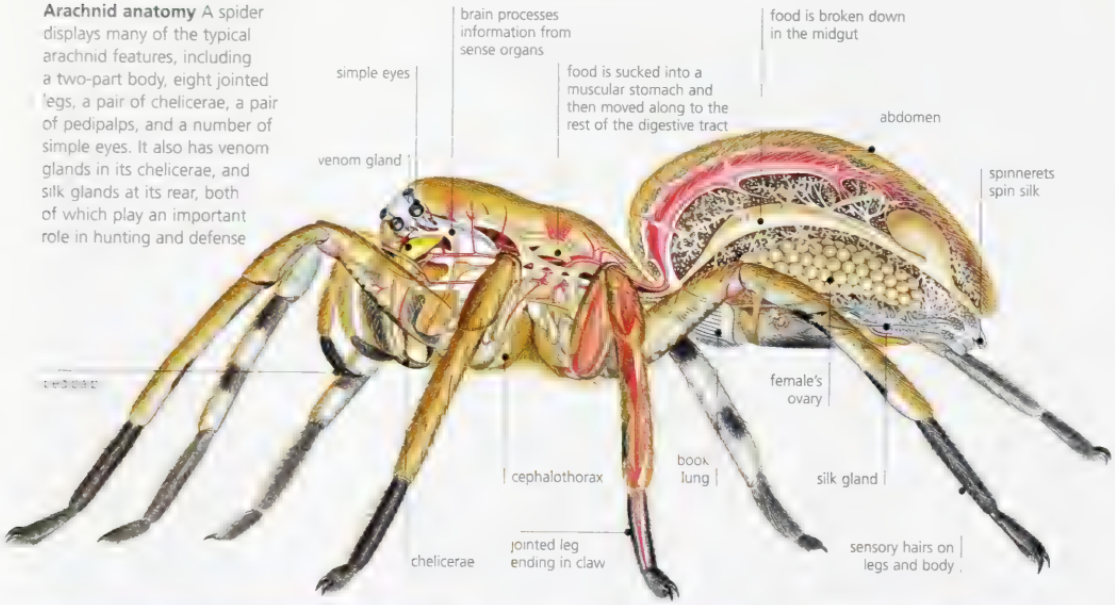
# ARACHNIDS

PHYLUM Arthropoda
SUBPHYLUM Chelicerata
CLASS Arachnida
ORDERS 17
FAMILIES 450
SPECIES 80,000

Including some of the most feared and fascinating of all invertebrates, the class Arachnida encompasses spiders, scorpions, harvestmen (or daddy-longlegs), and mites and ticks, along with several lesser known groups. Apart from some families of aquatic mites and a few species of water spiders, all arachnids are terrestrial, and the majority are predators of other invertebrates. Many spiders use silk webs to snare prey, and both scorpions and spiders inject their prey with venom to paralyze or kill it. Most arachnids are unable to swallow solid food and must squirt digestive enzymes into the prey and then suck the liquefied meal into their mouth.

**Diurnal vision** Most arachnid species are nocturnal and their simple eyes detect only variations in light. In daytime hunters, such as jumping spiders (family Salticidae), the two primary simple eyes provide very sharp vision at close range.

**Arachnid anatomy** A spider displays many of the typical arachnid features, including a two-part body, eight jointed legs, a pair of chelicerae, a pair of pedipalps, and a number of simple eyes. It also has venom glands in its chelicerae, and silk glands at its rear, both of which play an important role in hunting and defense



**Blood-sucking parasite** While most arachnids hunt live prey, ticks and some [illegible] parasites. A tick uses its hooked [illegible] to pierce the skin of a mamma[illegible] its blood. Once engorged, the [illegible]

**Stinging defense** While arachnids such [illegible]

## EIGHT-LEGGED PREDATORS

Like other arthropods, arachnids have a segmented body, a tough but flexible exoskeleton, and jointed limbs. Mites and ticks have rounded bodies made up of a single region, but other arachnids have two-part bodies, with a cephalothorax holding the eyes, mouthparts, and limbs, and an abdomen containing many of the internal organs.

Arachnids have eight legs, unlike insects, which have six. They also have two pairs of appendages near the mouth. The first pair, known as chelicerae, may be pincer-like or can form fangs that inject venom. They are used for subduing prey. The second pair, the pedipalps, are often used like antennae to sense the surroundings. Scorpions and some other arachnids use pedipalps to seize prey, while male spiders use them to transfer sperm to females.

To find prey and avoid danger, arachnids rely on the fine sensory hairs on their body and legs. They also have a number of simple eyes. Fine slits in the cuticle may detect odors, gravity, or vibrations.

Arachnids breathe using book lungs or a tracheal system, or both. Book lungs probably developed from gills and are made up of stacked leaves of tissue. The tracheal system takes air in through tiny pores called spiracles and distributes it to tissues via a network of tubes.

Development of arachnids is direct, with the young hatching as small versions of their parents and growing through a series of molts. Most arachnids are solitary.

**Whip-spider**
*Phrynichus* sp., order Amblypygi

Members of the order Amblypygi are known as whip-spiders or tailless whip-scorpions

**Book scorpion**
*Chelifer cancroides*, order Pseudoscorpiones

Book scorpions are often found living in books and furniture

**European buthid**
*Buthus occitanus*, order Scorpiones

**Hooded tick spider**
*Ricinoides sjoestedti*, order Ricinulei

Hood can be lowered over the mouth

**Fat-tailed scorpion**
*Androctonus australis*, order Scorpiones

Extremely long front legs act as tactile organs

**Whip-spider**
*Charinus milloti*, order Amblypygi

Venom glands in claw-like pedipalps

**Moss neobisid**
*Neobisium carcinoides*, order Pseudoscorpiones

The first pair of legs on a whip-scorpion is used as feelers

**Whip-scorpion**
*Thelyphonus caudatus*, order Uropygi

**Short-tailed whip-scorpion**
*Schizomus crassicaudatus*, order Schizomida

Can weigh more than 2 ounces (60 g) and will hunt small vertebrates such as mice and lizards, crushing them in its large pedipalps

**Emperor scorpion**
*Pandinus imperator*, order Scorpiones

## FACT FILE

**Order Scorpiones** Scorpions are distinguished from other arachnids by two large clawed pedipalps and a segmented abdomen. The tip of the tail holds a prominent stinger, which is sometimes used to subdue prey but more often plays a defensive role. Scorpions shelter in crevices or burrows by day, and hunt by night.

**Species** 1,400

Warmer regions; under rocks & bark

***Houseguest*** *The slenderbrown scorpion (Centruroides gracilis) usually lives in tropical forests, but may dwell in houses in regions where it has been introduced*

**Order Uropygi** Known as whip-scorpions or vinegaroons, the arachnids in this order resemble scorpions but their pedipalps are stouter, and their tails are long and thin. If threatened, a whip-scorpion will spray acid from glands at the base of its whip-like tail.

**Species** 100

Mainly tropical regions; under rocks

***Takeaway meals*** *The giant whip-scorpion (Mastigoproctus giganteus) seizes and crushes its invertebrate prey with its pedipalps, then carries the meal back to its burrow.*

## PARENTAL CARE

Most female arachnids lay their eggs in soil or another safe location and leave them to hatch on their own. In *Euscorpius carpathicus* (left) and other scorpions, however, the fertilized eggs develop inside the mother and she produces live young. The mother catches them in her first or first and second pairs of legs. At this stage, the larval young are rather helpless as they lack pedipalps and cannot sting. They crawl onto the mother's back and are ca[illegible] until after their first molt, about [illegible] 14 days later. Now equip[illegible] pedipalps and a fun[illegible] they are able to hunt [illegible] scatter to establish their [illegible] before their mother eats them.

## FACT FILE

**Order Araneae** This order contains the spiders, arachnids that have silk glands with which they produce webs and protective egg cases. All spiders are carnivorous, feeding mainly on other invertebrates, including other spiders. Web spiders build webs to snare their prey, while ground spiders are active hunters. Most spiders are venomous, injecting poison into prey or enemies through their fang-like chelicerae. Despite their fearsome reputation, they rarely bite humans unless they feel threatened, and only about 30 species will cause illness

Species 40,000

Worldwide; in all terrestrial habitats

***Night hunter*** *Wolf spiders such as Trochosa terricola are active nocturnal hunters and do not spin webs to catch their invertebrate prey*

## EYES OF THE SPIDER

Most spiders are nocturnal and tend to rely more on touch than on vision Day-active species, however, generally have excellent eyesight at close range Spiders usually have four pairs of simple eyes grouped in a characteristic pattern according to the family.

***Wide field*** *The huntsman spider (family Heteropodidae) is an active hunter Its wideset eyes provide all-round vision*

***Night hunter*** *The woodlouse-eating spider (family*

***Close range*** *The diurnal crab (family Thom ambushes insect prey*

*Coming to the dark*

House spider
*Tegenaria domestica*, order Araneae

Often encountered in houses and garden sheds

When threatened, this spider hides by stretching its long legs along a branch

Long-jawed spider
*Tetragnatha extensa*, order Araneae

Orb weaver
*Araniella cucurbitina*, order Araneae

European garden spider
*Araneus diadematus*, order Araneae

Wasp spider
*Agriope bruennichi*, order Araneae

Raft spiders sit on the surface of the water waiting for prey such as dragonflies, small fishes, and tadpoles

Raft spider
*Dolomedes fimbriatus*, order Araneae

Water spider
*Argyroneta aquatica*, order Araneae

Lives underwater in a bell-shaped, air-filled web

Cave spiders live in dark caves, mines, and railway tunnels

Cave spider
*Meta menardi*, order Araneae

## CAPTURE METHODS

Not all spiders sit waiting for prey to fall into their webs. The spitting spider (*Scytodes thoracica*) has an enlarged cephalothorax that houses linked venom and silk glands. It hunts its prey by night, stealthily approaching until it is within spitting distance. The spider then ejects two poisonous silk threads, covering the prey in a zig-zag pattern The prey is glued to the ground by the silk and paralyzed by the venom.

***Spitting spider*** *With only six small eyes, the spitting spider has poor vision and uses the sensory hairs on its front legs to find prey such as flies and moths*

Bolas spiders belong to the orb-weaver family, Araneidae, but they do not build orb webs. Instead, they "fish" for their prey, suspending a single strand of silk tipped with a sticky globule known as a bolas. The bolas seems to be laced with pheromones that mimic those of particular female noctuid moths. When male moths are attracted to the bolas and become stuck, the spider reels them in.

***Bolas spider***
*When it senses a moth approaching, a bolas spider will start swinging its fishing line in a circle.*

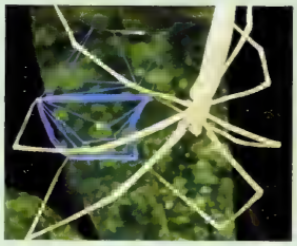
Spiders in various families have adapted their anatomy to convincingly mimic ants. They are even thought to produce pheromones that allow them to infiltrate ant colonies. Some ant-mimics use their disguise to prey on the unsuspecting ants. Others may merely be protecting themselves from predators such as wasps and birds that avoid ants because of the formic acid ants produce when threatened.

***Brazilian ant-mimicking spider*** *Like other ant-mimics,* Aphantochilus rogersi *has* [illegible] *partially divided into two segments to give the impression of* [illegible] *first pair of legs is held in fron* [illegible]

# SILK AND WEBS

While only some species build webs, almost all spiders produce silk. Made of the protein fibroin, spider silk is as strong as nylon thread but has greater elasticity. A spider may have up to eight silk glands in its abdomen, each yielding a different kind of silk. One kind of silk is used for the dragline a spider usually spins after itself like a mountain climber's safety line. Other types are used for cocooning fertilized eggs or wrapping up captured prey. Male spiders may use silk to hold their packages of sperm. Some spiderlings use threads of silk like balloons to carry them aloft so they can disperse. The best known use of silk is among the webspinning spiders, which build a remarkable variety of webs to snare their prey.

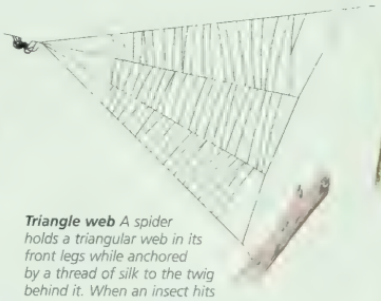
***Scaffold web*** *A scaffold web has stretched traplines with sticky ends attached to the ground. If a crawling insect walks into a trapline, the line snaps back, with the victim dangling in the air.*



**Captured prey** A net-casting spider (*Deinopus* sp.) prepares a little snare net each night and holds it in its legs as it awaits prey. When a potential victim passes by, the spider flings the net over it, quickly wraps the catch in extra silk, and then bites it.

***Lace-sheet web*** *The trap spun by a lace-web weaver is made of fine, woolly silk. It may not be sticky, but insects soon get tangled up in its many fibres, and remain trapped until the spider is ready for food.*

***Hammock web*** *The hammock web spun by a money spider over low bushes may look messy, but any insect caught in its fine lattice weave usually falls into another web suspended below.*



***Triangle web*** *A spider holds a triangular web in its front legs while anchored by a thread of silk to the twig behind it. When an insect hits the web, the spider releases its grip and the web collapses, entangling the prey.*

***Orb web*** *The most elaborate of all webs, the orb web covers a large area using a minimum of silk. An outer framework supports a continuous spiral and a series of spokes. The web is suspended between tree branches to capture flying insects.*

**No sticky feet** Spiders such as this orb weaver (*Argiope* sp.) (right) avoid getting trapped in their own webs because only some of the threads are sticky and they know where to tread.

**Shared nest** While most spiders are solitary, some share communal nests. Some species are truly colonial, and hunt and feed together. In others such as *Cryptophora* sp., each spider guards its own orb web and feeds alone, but the webs share frame lines, creating a vast network of silk threads.

## SPIDER FANGS

Spiders paralyze or kill their prey by stabbing it with their fang-tipped chelicerae, which inject venom from the poison glands. The chelicerae are also sometimes used to carry prey items, transport eggs, or dig burrows

***Fang directions*** *In primitive spiders such as tarantulas, the chelicerae strike downward on the victim (above left), but in most species, they close together like pincers (above right)*

## DEADLY TOXINS

While many spiders can deliver a painful bite, only a handful have venom that can seriously harm humans. The most potentially dangerous spiders include funnel-webs, some tarantulas, the black widow, and the brown recluse (*Loxosceles reclusa*)

***Fatal bite*** *The Sydney funnel-web (Atrax robustus) may be the deadliest spider. It rears up to stab prey or defend itself*

## COURTSHIP RITUALS

When a male spider is ready to mate, he fills his pedipalps with a capsule of sperm called a spermatophore and searches for a female, aided by the pheromones that mature females emit In most species, mating is preceded by courtship. This may involve the male performing a particular dance; drumming the ground with the feet; plucking a silk thread attached to the female's web; or repeatedly touching the female. Fertilization is indirect. If the female is receptive, the male inserts his spermatophore-bearing pedipalps into the female's spermatheca, an internal sac where the sperm are stored until she is ready to lay her eggs

***Love at sight*** *[illegible] keen vision, [illegible] spiders use [illegible] in courtsh[illegible] the male [illegible] a com[illegible] dance [illegible] the female*

## FACT FILE

**Order Opiliones** The harvestmen, or daddy-longlegs, in this order differ from spiders in that they lack venom glands, silk glands, and a waist. Most species have very long, fine legs. Unlike most other arthropods, fertilization is direct, with the male using a penis to deposit sperm in the female.

Species 5,000

Worldwide, in leaf litter & under stones

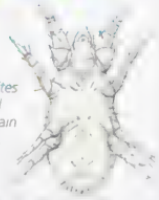
***Bringing in the harvest*** *The harvestman Phalangium opilio looks for small arthropods in the leaf litter. It is also common in crops, where it feeds on pests such as aphids*

**Subclass Acari** Classified in seven orders in the subclass Acari, mites and ticks are the most varied and abundant arachnids. They flourish in almost every kind of habitat, from polar caps to deserts, thermal springs to ocean trenches. With some species small enough to live inside a human hair follicle, however, mites are so tiny that they are rarely noticed. Ticks tend to be larger, but rarely exceed ½ inch (1 cm) in length. Mites and ticks have only six legs when they hatch as larvae and acquire an extra pair as nymphs before becoming adults.

Species 30,000

Worldwide

***Dust to dust*** *Flour mites (Acarus siro) are found living in the dust of grain crops, in animal cages, and in food stores.*



### DISEASE SPREADERS

While most members of Acari are free-living inhabitants of soil, leaf litter, and water, some are parasites of other animals or plants. Those mites and ticks that feed on vertebrates often transmit bacteria that cause potentially fatal diseases in humans. Several species of ticks also commonly trigger acute paralysis in humans and domestic animals.

***Sick tick*** *The European*

**Bulb mite**
*Rhizoglyphus echinopus*, subclass Acari

Harvestmen have scent glands that release a pungent odor when the arachnid is threatened

**Harvestman**
*Opilio parietinus*, order Opiliones

**Harvestman**
*Phalangium opilio*, order Opiliones

*Trogulus tricarinatus*, order Opiliones

One of the fastest arthropods, the camel spider runs on only three pairs of legs; it uses the first pair as feelers to detect prey such as lizards and mice

**Camel spider**
*Galeodes arabs*, order Solifugae

*Ischyropsalis helwigii*, order Opiliones

*Phthiracarus* sp., subclass Acari

The pigeon tick can spread relapsing fever and other diseases

**Sheep tick**
*Dermacentor marginatus*, subclass Acari

**Pigeon tick**
*Argas reflexus*, subclass Acari

*Ctenoglyphus palmifer*, subclass Acari

Scabies mite
*Sarcoptes scabiei*, subclass Acari

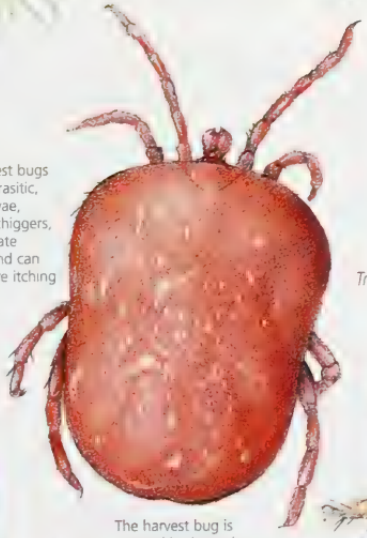
The scabies mite causes mange in humans and animals, leading to hair loss, dermatitis, and weight loss

*Demodex canis*, subclass Acari

*Demodex canis* lives in the hair follicles and sebaceous glands of most dogs and can cause mange

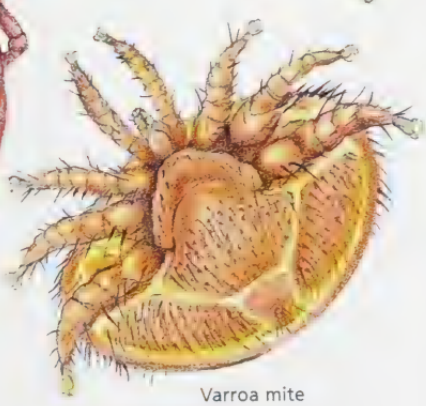
Pear bud mite (leaf blister mite)
*Eriophyes piri*, subclass Acari

Adult harvest bugs are non-parasitic, but the larvae, known as chiggers, are vertebrate parasites and can cause severe itching



Harvest bug
*Trombidium holosericeum*, subclass Acari

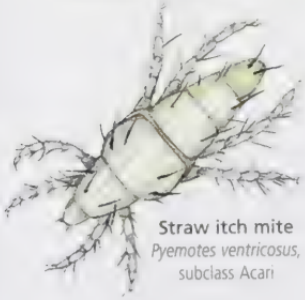
The harvest bug is covered in tiny red hairs that create the appearance of velvet



Varroa mite
*Varroa jacobsoni*, subclass Acari

Poultry red mite
*Dermanyssus gallinae*, subclass Acari

The straw itch mite is a parasite of insect larvae found in stored grain and straw; it can cause itchy dermatitis in humans



Straw itch mite
*Pyemotes ventricosus*, subclass Acari

*Phytoseiulus persimilis* preys on spider mites and is deliberately used to control them in greenhouses

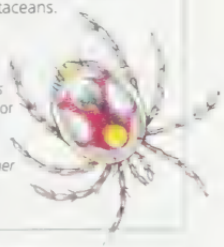
*Phytoseiulus persimilis*, subclass Acari

Spider mite
*Tetranychus telarius*, subclass Acari

Spider mites feed on the underside of leaves, causing them to yellow and die

## AQUATIC MITES

Some mites have adapted to a life in water. They are found in every kind of freshwater habitat, from puddles to deep lakes, hot springs to raging rivers. Some have also colonized the ocean, where they live on mudflats, coral reefs, and the seafloor, absent only from open waters. While semiaquatic mites are found in many groups within Acari, more than 40 families of fully aquatic mites are gathered in the subcohort Hydracarina. These mites lay their eggs underwater on stones or plants or in sponges or mussels. The larvae are parasitic and quickly attach themselves to an invertebrate host. As the host is often a flying insect such as a dragonfly, it not only provides the mite larva with food, but also disperses it to a new body of water. As nymphs and adults, water mites are predators and feed on other mites, aquatic insects, and crustaceans.



***Bright warning*** *Water mites such as Brachypoda versicolor often display bright colors, possibly to warn fishes and other predators that they are distasteful.*

## HONEYBEE THREAT

A honeybee colony can be severely harmed or even killed by the varroa mite (*Varroa jacobsoni*). An adult female mite moves into a honeybee's brood cell to lay her eggs. Both the mite and her hatched offspring then feed on the bee larva as it matures. The mite offspring mate while still in the brood cell. The males then die, but the females emerge attached to the young adult bee. The female mites then find another brood cell where they can deposit their eggs. Parasitized honeybee pupae tend to emerge as weak, deformed adults.

***Snug fit*** *The varroa mite usually inserts itself between the honeybee's body segments, making it difficult to see*

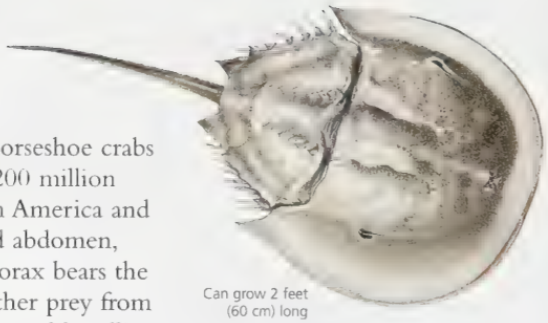
## CONSERVATION WATCH

**Arachnid alert** The conservation movement has paid little attention to arachnids. Only 18 species have been assessed by the IUCN, but all of these are on the Red List. Further research is needed, but arachnid diversity is no doubt threatened by habitat loss, pollution, pesticide use, and invasive exotic species.

# HORSESHOE CRABS

PHYLUM Arthropoda
SUBPHYLUM Chelicerata
CLASS Merostomata
ORDER Xiphosura
FAMILY Limulidae
SPECIES 4

More closely related to arachnids than to crustaceans, the horseshoe crabs of the class Merostomata have changed little in the past 200 million years. The four living species, found off the east coasts of North America and Asia, are marine. Their body is made up of a cephalothorax and abdomen, each protected by a hard shell. The horseshoe-shaped cephalothorax bears the pincer-like chelicerae, which are used for seizing worms and other prey from the muddy seafloor, and five pairs of legs, used for both walking and handling food. The formidable tail spine, or telson, does not act as a weapon but helps the horseshoe crab to right itself and to plow through mud.




**Horseshoe crab**
*Limulus polyphemus*

**Time to breed** Breeding horseshoe crabs gather on beaches in spring. The eggs are buried in the sand just below the high-tide mark, where they stay moist but are warmed by the sun.

## SEA AND SHORE

Horseshoe crabs spend most of their time on the seafloor at depths of about 100 feet (30 m), breathing through book gills on the abdomen. They push through mud, and can also swim on their back and walk.

In spring, horseshoe crabs come ashore to breed. A male will cling onto a female's back as she makes her way over the tidal zone. The female scoops out holes in the sand and lays up to 300 eggs in each, and the male then covers the eggs with sperm to fertilize them. The larvae reach adulthood after about 16 molts over 9 to 12 years.

# SEA SPIDERS

PHYLUM Arthropoda
SUBPHYLUM Chelicerata
CLASS Pycnogonida
ORDER Pantopoda
FAMILIES 9
SPECIES 1,000

With their long legs, sea spiders bear a superficial resemblance to spiders, but they evolved separately and have many unique features. A sea spider's body is greatly reduced. The small head region, known as the cephalon, holds a long proboscis with the mouth; four simple eyes on a stalk; and, usually, two chelicerae (to grasp prey) and two pedipalps (used as sensors). It also bears the first pair of walking legs and a pair of appendages called ovigers, used for grooming and egg-carrying. A segmented trunk holds another three pairs of legs, and leads to a tiny abdomen at the rear. Because the abdomen is so small, the digestive and reproductive organs extend into the legs.

**Antarctic forms** Both the red sea spider (*Pycnogonum decalopoda*) and the smaller spider (*P. nymphon*) live under the sea ice.

**Gracile sea spider**
*Nymphon gracile*

**Littoral sea spider**
*Pycnogonum littorale*

## BOTTOM-DWELLERS

Sea spiders live in every ocean, from warm, shallow waters to icy depths of 23,000 feet (7,000 m). Most are small, but some deep-sea species have a leg-span of up to 28 inches (70 cm). Although some sea spiders can swim, most are bottom-dwellers and feed on soft-bodied invertebrates such as sponges and corals.

To breed, a female sea spider releases her eggs into the water and the male covers them with sperm. The male then carries the fertilized eggs on his ovigers until they hatch.

# MYRIAPODS

**PHYLUM** Arthropoda
**SUBPHYLUM** Myriapoda
**CLASSES** 4
**ORDERS** 20
**FAMILIES** 140
**SPECIES** 13,500

Centipedes (class Chilopoda), millipedes (class Diplopoda), symphylids (class Symphyla), and pauropods (class Pauropoda) are all myriapods with long, segmented bodies; simple eyes; a pair of jointed antennae; and numerous pairs of legs. Most centipedes are carnivores and hunt through leaf litter for other small invertebrates. They paralyze prey with a pair of venomous fangs on the underside of the head that can deliver a nasty bite even to humans. Millipedes are plant-feeders and do not bite, but many react to danger by curling into a coil and emitting a toxic substance. Resembling tiny centipedes, symphylids and pauropods live in leaf litter and soil and feed on decaying plant matter.

**Coiled defense** A forest log millipede (*Narceus americanus*) has curled into the typical millipede defensive posture that leaves only the tough, calcareous plates of its exoskeleton exposed. It may also squirt out a pungent, irritating liquid.

**Tropical species** Centipedes are most diverse in tropical forests. Their many legs can be short and hooked, or long and slender. The final pair may be antenna-like (as in the *Scutigera* sp. above) or pincer-like

## MANY LEGS

Centipedes have flattened, worm-like bodies, with one pair of legs attached to each body segment except the last. They have at least 15 and as many as 191 pairs of legs. The largest centipede, *Scolopendra gigantea* of the American tropics, can grow to 11 inches (28 cm) long. It is strong enough to prey on mice, frogs, and other small vertebrates.

A millipede's body is rounded and made up of doubled segments known as diplosomites, most of which bear double pairs of legs. Millipedes range from 1/12 inch to 11 inches (2 mm to 28 cm) long, and have up to 200 pairs of legs.

Measuring no more than ½ inch (1 cm) in length, symphylids have 12 pairs of legs. Pauropods are even smaller, at less than 1/12 inch (2 mm) long, and bear nine pairs of legs.

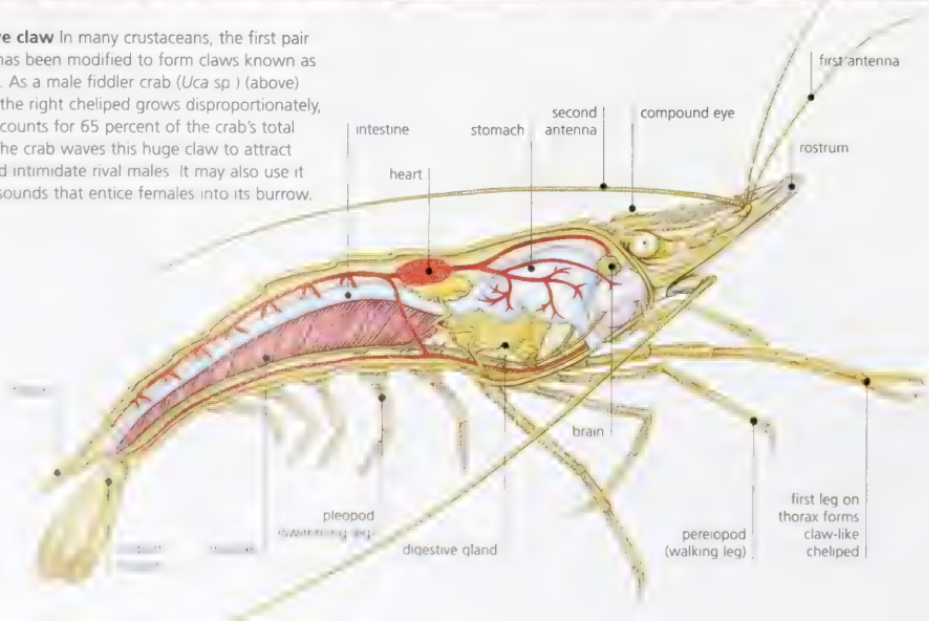
Most myriapods are nocturnal, live in moist forests, and tend to be hidden in leaf litter or soil or under rocks or logs. Some species, however, are found in grasslands or deserts. Millipedes usually lay their eggs in a soil nest, while some centipedes curl around their eggs and young to protect them.

# CRUSTACEANS

PHYLUM Arthropoda
SUBPHYLUM Crustacea
CLASSES 11
ORDERS 37
FAMILIES 540
SPECIES 42,000

From water fleas less than 1/100 inch (0.25 mm) long, to giant spider crabs with legs spanning 12 feet (3.7 m), crustaceans are an extraordinarily diverse group. Although some species have adopted a terrestrial lifestyle, it is in aquatic environments that crustaceans have flourished, gradually evolving to exploit every marine and freshwater niche. Free-swimming planktonic species, such as krill, form the basis of vast aquatic food webs. Crabs and other bottom-dwellers may burrow into or crawl over the sediment. Barnacles remain cemented in place, filtering food from the water. There are also parasitic crustaceans, some of which exist in their adult form as a collection of cells inside the host.

**Attractive claw** In many crustaceans, the first pair of limbs has been modified to form claws known as chelipeds. As a male fiddler crab (*Uca* sp.) (above) matures, the right cheliped grows disproportionately, until it accounts for 65 percent of the crab's total weight. The crab waves this huge claw to attract mates and intimidate rival males. It may also use it to make sounds that entice females into its burrow.




**Shrimp design** Like most crustaceans, shrimps have two pairs of antennae, the second of which is highly mobile; a pair of compound eyes, each with as many as 30,000 lenses; and specialized limbs. A shrimp's blood is pumped by a heart, and it breathes through gills attached to its legs

**LAND INVADERS**

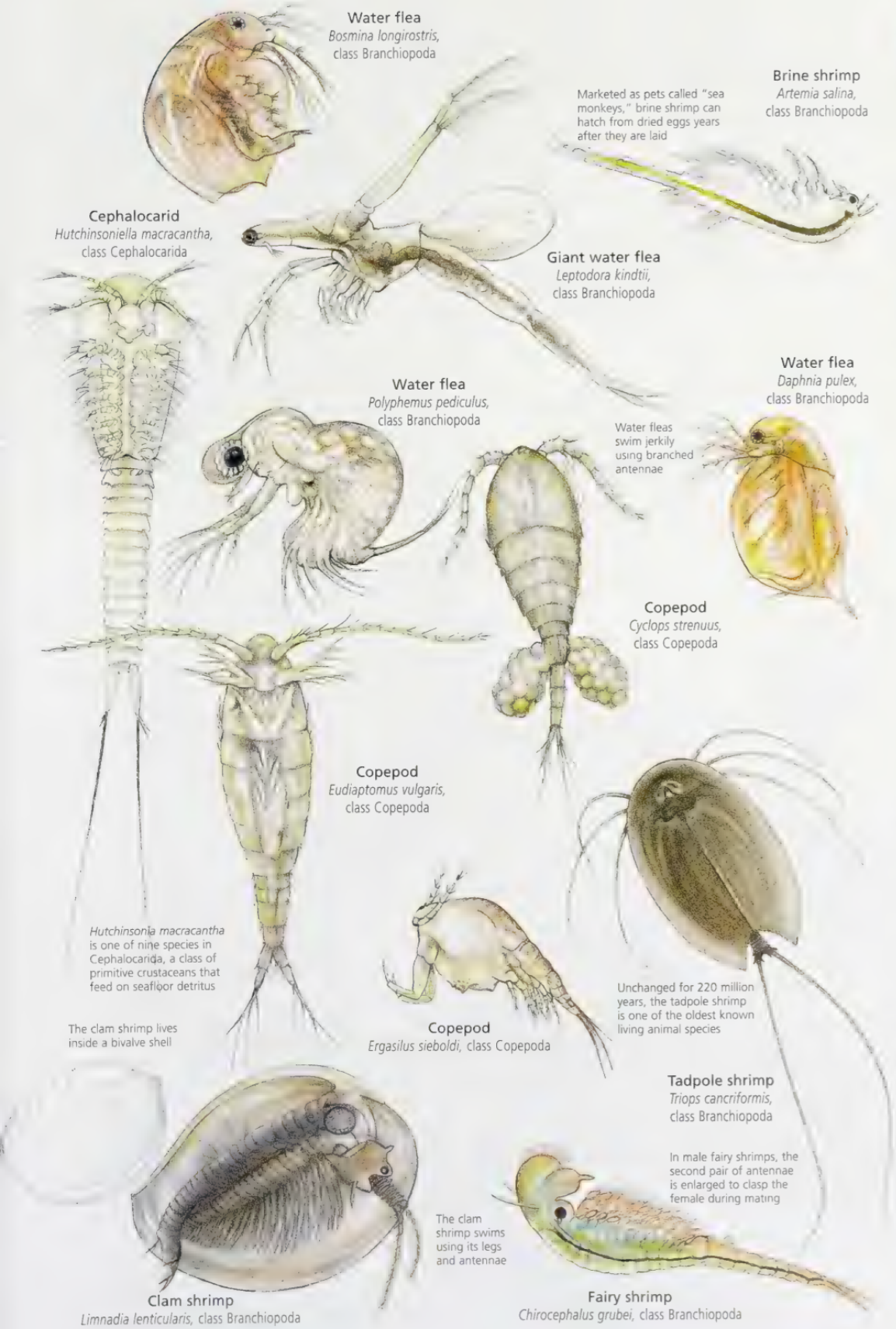
While crustaceans are abundant in water, only a minority have adapted to life on land. These tend to live in damp places and some return to water to breed. Sometimes known as pill bugs or sow bugs, the wood lice of family Oniscoidea are the most terrestrial crustaceans and even include a few desert species. Some wood lice curl into a tight ball when threatened (below). The limited exploitation by crustaceans of land habitats can be attributed to the lack of a waxy, water-tight cuticle and the reliance on gills for breathing.

## CRUSTACEAN ANATOMY

Like other arthropods, crustaceans have a segmented body, jointed legs, and an exoskeleton, and grow by molting. The exoskeleton can be thin and flexible, as in water fleas, or rigid and calcified, as in crabs. The body usually has three regions—head, thorax, and abdomen—but in many of the larger species, the head and thorax form a cephalothorax, which is protected by a shield-like carapace. The abdomen often has a tail-like extension called a telson.

A typical crustacean's head holds two pairs of antennae; a pair of compound eyes, often on stalks; and three pairs of biting mouthparts. The thorax and sometimes the abdomen carry the limbs, each of which usually has two branches. In many species, particular limbs have become specialized for walking, swimming, food collection, or defense. Crabs, for example, have modified their first pair into claws called chelipeds.

While some female crustaceans lay eggs in water, many brood eggs on their body. The eggs of some species hatch into free-swimming nauplius larvae, with two pairs of antennae, a pair of mandibles, and a single simple eye. In most species, the eggs hatch at a more advanced stage or even as miniature adults.




## FACT FILE

**Class Branchiopoda** The tadpole shrimps, water fleas, clam shrimps, and fairy or brine shrimps in this class are all small, ranging from 1/100 inch to 4 inches (0.25 mm to 10 cm) in length. They have leaf-like legs, which they use to gather food, swim, and breathe. Found in almost every freshwater body in the world, branchiopods include species that live in temporary pools and survive dry spells as dormant eggs.

Species 800

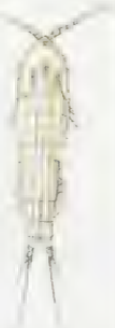
Worldwide; mainly fresh water

***Backstroker***
*Fairy shrimps such as* Branchipus stagnalis *swim on their back, using their legs to filter organic particles from the water.*

**Class Copepoda** Found in vast numbers in the oceans, copepods are a crucial link in the marine food web. The body tends to be cylindrical. They lack compound eyes, but have a single simple eye retained from the nauplius larval stage. Some species are parasitic on fish and other aquatic animals.

Species 8,500

Worldwide; mainly marine

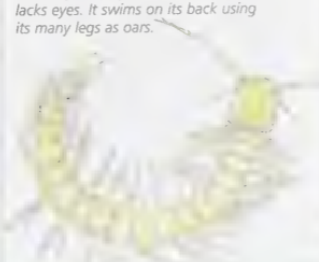


***Forked tail***
Canthocamptus staphylinus *displays the branched telson (tail-like projection) typical of copepods.*

## RECENT DISCOVERY

When *Speleonectes lucayensis* was discovered in a sea cave in the Bahamas in 1981, it prompted the description of a new class of crustacean, Remipedia. Since then, several more species, all found in Caribbean or Australian caves connected to the sea, have been added to the class. These primitive forms have long, worm-like bodies with up to 32 segments, each bearing a pair of legs. They are carnivorous.

***Swimming blind*** *Like other members of Remipedia,* Speleonectes lucayensis *lacks eyes. It swims on its back using its many legs as oars.*



## FACT FILE

**Class Cirripedia** The only sessile group of crustaceans, the barnacles that make up the class Cirripedia are entirely marine. Barnacles were believed to be mollusks until 1830, when it was discovered that they hatch from eggs as free-swimming nauplius larvae and therefore are crustaceans. The larvae mature and cement themselves head-down to rocks or boats or to hosts such as fish, turtles, and whales. Most adult barnacles are protected by calcareous plates and collect food particles from the water with their long, feathery legs (cirri). Barnacles are hermaphrodites. They live in tightly packed communities and can internally fertilize one another.

Species 900

Worldwide; in marine waters

**Class Ostracoda** Known as mussel shrimps or seed shrimps, the members of this class are distinguished by their carapace, which takes the form of a hinged, bivalve shell. Only the antennae and end bristles of the legs emerge from the shell.

Species 6,000

Worldwide; in all types of water bodies

***Self-reproducing*** *The ostracod* Ilyocypris gibba *can reproduce sexually but most often uses parthogenesis, with larvae developing from unfertilized eggs.*

## TOTAL INVASION

The parasite *Sacculina carcini* can only be recognized as a barnacle by its free-swimming nauplius larvae. When a female larva has matured, it invades a host, usually the green crab (*Carcinus maenas*). The larva metamorphoses into a needle-like form that injects cells into the host. The cells form a root-like system, called an interna, throughout the crab's body. The interna eventually develops a reproductive body, an externa, outside the crab. Male larvae attach to the externa, into which they release cells that develop into sperm. Fertilization results in nauplius larvae.

Freshwater fish louse
*Argulus foliaceus*, class Branchiura

Adult fish lice parasitize freshwater fish, feeding on the skin or in the gills of the host and causing tissue damage

Acorn barnacle
*Balanus tintinnabulum*, class Cirripedia

Acorn barnacles use their feathery cirri to sweep plankton from the water, but can retract them behind a trapdoor when the tide is out

Ostracod
*Cypris pubera*, class Ostracoda

Ostracod
*Candona suburbana*, class Ostracoda

Like other members of the small class Mystacocarida, *Derocheilocaris remanei* lives among sand grains in the intertidal zone

Mystarocarid
*Derocheilocaris remanei*, class Mystacocarida

Primitive barnacle that parasitizes brittle stars

Barnacle
*Ascothorax ophioctenis*, class Cirripedia

*Conchoderma auritum* attaches to the skin of a whale, but does not feed on the host's body, filtering food from the water instead

Barnacle
*Conchoderma auritum*, class Cirripedia

Goose barnacles live in large clusters, usually in deep water, attached by flexible stalks to surfaces such as rock and wood

Goose barnacle
*Lepas anatifera*, class Cirripedia

*Parastygocaris andeni,*
class Malacostraca, order Stygocaridacea

**Amphipod**
*Caprella anatifera,* class Malacostraca,
order Amphipoda

*Thermosbaena mirabilis,*
class Malacostraca,
order Thermosbaenacea

*Diastylis rathkei,*
class Malacostraca,
order Cumacea

All stomatopods have large raptorial appendages for spearing or smashing their aquatic prey

**Opossum shrimp**
*Mysis relicta,*
class Malacostraca, order Mysidacea

**Mantis shrimp**
*Odontodactylus scyllarus,*
class Malacostraca, order Stomatopoda

**Amphipod**
*Gammarus fossarum,*
class Malacostraca, order Amphipoda

*Armadillidium vulgare* is a fully terrestrial species that lives and breeds on land, brooding its eggs in a fluid-filled pouch

*Bathynella natans,*
class Malacostraca,
order Bathynellacea

**Common pill wood louse**
*Armadillidium vulgare,*
class Malacostraca,
order Isopoda

*Bathynella natans* is a subterranean crustacean that lives in gravel near lakes

**Tasmanian mountain shrimp**
*Anaspides tasmaniae,*
class Malacostraca,
order Anaspidacea

Having changed little in the past 250 million years, the Tasmanian mountain shrimp is considered a "living fossil"

*Nebalia bipes,*
class Malacostraca,
order Leptostraca

**Giant isopod**
*Bathynomus giganteus,*
class Malacostraca,
order Isopoda

**Aquatic sowbug**
*Asellus aquaticus,*
class Malacostraca, order Isopoda

## FACT FILE

**Class Malacostraca** By far the largest class of crustaceans, Malacostraca contains 13 orders. Almost all species have six head segments, eight thoracic segments, and six abdominal segments. Except for the first head segment, each segment usually bears two appendages.

**Species** 25,000

Worldwide; mainly aquatic

***Familiar crustaceans*** *The class Malacostraca includes Daum's reef lobster (*Enoplometopus daumi*), which joins other lobsters, crabs, and shrimps in the order Decapoda*

**Order Amphipoda** These small, widespread members of the class Malacostraca are found in marine, freshwater, and moist terrestrial habitats. An amphipod's body is usually flattened laterally, often creating a shrimp-like appearance.

**Species** 6,000

Worldwide; mainly aquatic

***Varied salinities*** *The amphipod* Corophium volutator *lives in U-shaped burrows in saltwater, brackish, and freshwater habitats*

**Order Isopoda** Like amphipods, isopods belong to Malacostraca. Their bodies are flattened dorsoventrally (from the back to the belly). They include the truly terrestrial wood lice, but most species crawl along the bottom of aquatic habitats.

**Species** 4,000

Worldwide; mainly marine

***Aquatic isopod*** *Like amphipods, isopods such as* Astacilla pusilla *lack a carapace. Most are aquatic and can crawl and swim. They tend to be omnivorous scavengers.*

## PREDACIOUS EYES

The Stomatopoda is a highly specialized order in the class Malacostraca. Known as mantis shrimp, its members actively prey on fish, crabs, and mollusks. Their success as predators depends not only on their raptorial appendages, but also on their complex compound eyes.

*Stomatopod vision*

*vision and depth perception (perspective)*

## FACT FILE

**Order Decapoda** Named after their five pairs of thoracic legs, decapods present the most recognizable of all crustacean species. They can be divided into swimmers, which include shrimps and lobsters, and those which include crabs, and crabs. In many species the first pair of legs, the chelipeds, form heavy pincers and are used to capture prey. Some species, however, are filter-feeders, detritus-feeders, or plant-feeders. Typically, decapods carry their fertilized eggs on their body. Most larvae hatch as a crab, a tiny organism that is mostly head with appendages and a long spine out front.

Species: 5,000

*Noisy crab* A male noisy crab, showing the right claw, which is capable of producing loud and piercing sounds by rubbing its overlarged right cheliped against protrusions on its body. The species

## CRUCIAL KRILL

The small order Euphausiacea comprises about 85 species of krill, planktonic creatures with a shrimp-like body form. They are a crucial link in marine food webs, particularly in the Antarctic, where the southern krill, *Euphausia superba*, is the keystone species. Krill usually spend the day in the ocean depths, but gather in swarms at the surface to feed at night. Most species are filter-feeders and have phosphorescent with feathered legs. They may also use their feathered legs to form a net, which they pass through many times, using, between, between and back. Many krill species have active light-producing organs. The bioluminescence probably ranges from from warning and frightening.

*Southern krill* The southern krill, *Euphausia superba*, is a key species in the food chain of the Antarctic. Its life span is about five years.

*Northern krill* The northern krill, *Meganyctiphanes norvegica*, is a key species in the food chain of the North Atlantic.

**Emperor shrimp**
*Periclimenes imperator*, class Malacostraca, order Decapoda

The emperor shrimp lives on hosts such as sea snails and sea cucumbers for protection and transport

**Banded coral shrimp**
*Stenopus hispidus*, class Malacostraca, order Decapoda

**Randall's pistol shrimp**
*Alpheus randalli*, class Malacostraca, order Decapoda

**Brown shrimp**
*Crangon crangon*, class Malacostraca, order Decapoda

The cleaner shrimp feeds on parasites that it cleans off passing fish

**Cleaner shrimp**
*Lysmata amboinensis*, class Malacostraca, order Decapoda

**Kuiter's dancing shrimp**
*Rhynchocinetes kuiteri*, class Malacostraca, order Decapoda

**Black tiger prawn**
*Penaeus monodon*, class Malacostraca, order Decapoda

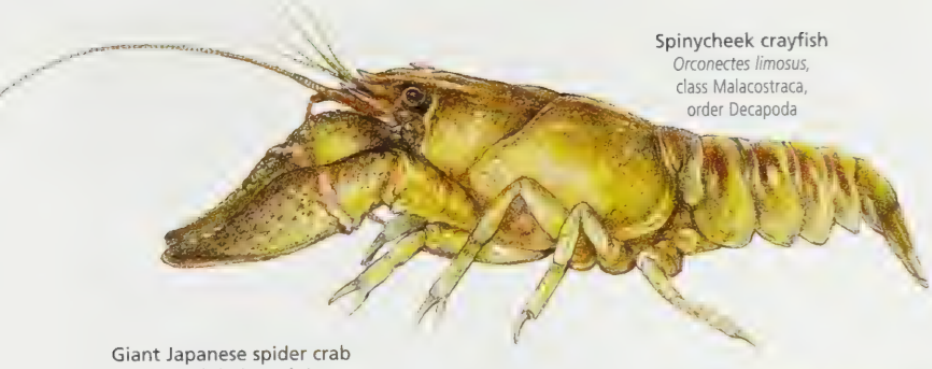
**Painted spiny lobster**
*Panulirus versicolor*, class Malacostraca, order Decapoda

The Atlantic lobster is such an important fishery species that it is often known as the "king" of seafood.

**Atlantic lobster (American lobster)**
*Homarus americanus*, class Malacostraca, order Decapoda

Young lobsters are the largest species of true lobsters.

**Spiny lobster**
*Palinurus elephas*, class Malacostraca, order Decapoda



**Spinycheek crayfish**
*Orconectes limosus,*
class Malacostraca,
order Decapoda

**Giant Japanese spider crab**
*Macrocheira kaempferi,*
class Malacostraca, order Decapoda

With legs spanning 12 feet (3.7 m), the giant Japanese spider crab is the largest of all arthropods

The slipper lobster uses its spade-like appendages to burrow into mud, sand, or gravel

**Slipper lobster**
*Scyllarus arctus,*
class Malacostraca,
order Decapoda

**Horn-eyed ghost crab**
*Ocypode ceratophthalma,*
class Malacostraca,
order Decapoda

**European green crab**
*Carcinus maenas,*
class Malacostraca,
order Decapoda

The Chinese mitten crab's common name was inspired by dense patches of hair on its chelipeds

**Chinese mitten crab**
*Eriocheir sinensis,*
class Malacostraca, order Decapoda

An Asian species, the Chinese mitten crab has been introduced in Europe and North America, where it is having a severe impact on native species

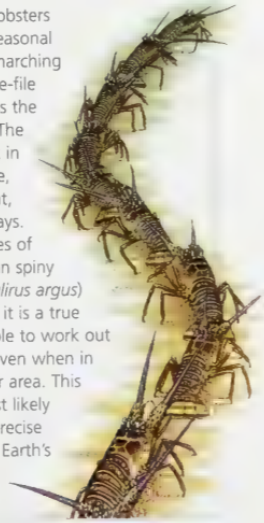
**Alaskan king crab**
*Paralithodes camtschatica,*
class Malacostraca,
order Decapoda

## CRUSTACEAN MIGRATIONS

**From land to sea** Land crabs have adopted a terrestrial lifestyle, but some return to water to breed. As adults, the red crabs (*Gecarcoidea natalis*) of Christmas Island live in the humid, inland rain forest. When it is time to lay eggs, the island's entire population of 40 million crabs undertakes a perilous week-long journey back to the coast.

Males arrive first and dig the nesting burrows. After mating, the females brood their eggs for about 2 weeks, and then release them in the ocean. Few of the aquatic larvae survive, but those that do will return to shore after a month and molt into young terrestrial crabs that slowly move inland.

**Across the ocean floor**
Some spiny lobsters embark on seasonal migrations, marching in long, single-file queues across the ocean floor. The lobsters walk in a straight line, day and night, for several days. Recent studies of the Caribbean spiny lobster (*Panulirus argus*) indicate that it is a true navigator, able to work out its location even when in an unfamiliar area. This ability is most likely linked to a precise detection of Earth's magnetic fields.



## PORTABLE HOMES

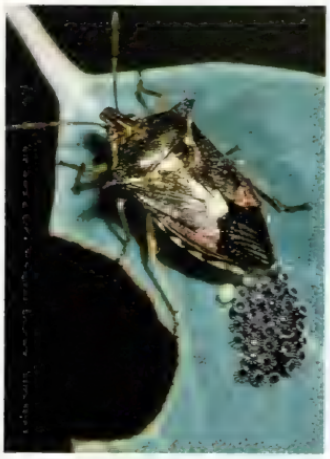
To protect their soft abdomens, hermit crabs (family Paguridae) and most land hermit crabs (family Coenobitidae) live in the abandoned shells of gastropods. As the crabs grow, they must find larger shells to move into. Two crabs will often fight over a desirable shell.

# INSECTS

PHYLUM Arthropoda
SUBPHYLUM Hexapoda
CLASS Insecta
ORDERS 29
FAMILIES 949
SPECIES >1 million

By most measures, insects are the most successful animals ever to have lived on Earth. With about a million described species, they account for more than half of all known animal species, and many more insects are still to be discovered, with estimates of the total number of insect species ranging from 2 million to 30 million. In terms of sheer numbers, insects overwhelm all other animal forms: some scientists believe that ants and termites alone make up 20 percent of the world's animal biomass. Some form of insect has managed to colonize the hottest deserts and the coldest polar zones, as well as virtually every land and freshwater habitat in between, and a handful live in the sea.

**Extreme habitats** Brine flies (family Ephydridae) are found along the shores of California's saline Mono Lake, where their larvae feed on algae. Other insects have been found living in pools of crude oil, in hot springs, and in the ice of Antarctica.



**Parental guard** Most insects indicate the parental care, depositing large numbers of eggs and then leaving them to hatch by themselves. Some shield bugs, however, will guard their eggs and then, like with the mommy [illegible] [illegible] [illegible].

**Pollinators** [illegible] honeybee as it [illegible] from a flower. After the bee visits the plant flower, some pollen will be dropped. Most flowering plants rely on insects for pollination and have evolved flowers with different shapes, colors, and odors to attract particular species, and have fixed flowering periods, flies flies.

### CONSERVATION WATCH

Of the 1 million known species of insects, only 768 have been assessed by the IUCN. Of these, 97% are listed on the Red List, as follows:

- [illegible] Extinct, or extinct in wild
- 96 Critically endangered
- [illegible] Endangered
- [illegible] Vulnerable
- [illegible] Conservation dependent
- [illegible] Near threatened
- [illegible] Data sufficient

## SUCCESS STORY

Insects owe their incredible success to various aspects of their biology. Their tough, flexible exoskeleton provides protection without overly restricting movement. It is covered in a waxy coating that minimizes moisture loss, enabling insects to survive in dry conditions.

As the first creatures and the only invertebrates ever to develop powered flight, insects were able to find both food and mates, evade their predators, and colonize new areas with great efficiency. In most species, the wings can be folded over the body when at rest, so that the insect can exploit confined spaces inside bark, dung, leaf litter, or soil, for example.

Insects breathe through spiracles, small openings in the sides of their body that can be closed to prevent moisture loss. Rather than being transported around the body in the blood, oxygen is distributed directly into the body tissues by a series of tiny pipes known as tracheae. This method of gas diffusion works well only over short distances, which may be the main reason insects have remained small. Most insects are no more than an inch or two (a few centimeters) long. Their small size allowed insects to take advantage of a wide range of microhabitats, a major factor in their great diversity.

Sensory organs are scattered over an insect's body. The head usually has two compound eyes as well as three simple eyes, or ocelli. The two antennae can detect scent, taste, touch, and sound. Hearing organs

**Purpose-built mouthparts** The highly varied feeding habits of insects are reflected by the shape of their mouthparts. A moth (above) has a long, coiled tube, or proboscis, that can be unfurled to collect nectar. Mosquitoes have beaks that can pierce the skin of prey and suck up the body fluids, while aphids have piercing mouthparts for gathering plant juices. The mandibles, or jaws, of carnivorous insects such as ground beetles are sharp for cutting, while those of herbivores such as grasshoppers are adapted for grinding.

**Spontaneous young** Scarab beetles (family Scarabaeidae) roll up their sturdy, front legs to roll dung into a large ball that may be taken underground as food, or used by the female as a nest for her eggs. Possibly because the young seemed to suddenly erupt from the dung, scarab beetles were revered by the ancient Egyptians.

**Insect anatomy** While insects display a staggering diversity of shapes and forms, they follow the same basic body plan. Like other arthropods, insects have segmented bodies made up of a head, thorax, and abdomen; segmented limbs; and a tough exoskeleton. They are distinguished by having three pairs of legs and, usually, two sets of wings, a single pair of antennae, and a pair of compound eyes.

can also be on the body or legs. Other sensors detect changes in air pressure, humidity, and temperature.

The life-cycles of many insects allow for very rapid reproduction, enabling populations to respond quickly to favorable conditions and recover from catastrophes. Most insects use internal fertilization, but the female is able to store the male's sperm and use it over time. Some insects, such as aphids, can reproduce without fertilization to rapidly increase their numbers, but also use sexual reproduction to ensure genetic diversity. Insect eggs are protected by a shell-like membrane called the chorion that prevents them from drying out, another factor in the successful colonization of dry habitats. While some insects resemble small versions of their parents when they hatch, most do not and must go through some form of metamorphosis. The juveniles and adults often occupy different ecological niches and eat different foods, which helps to avoid competition between them.

Because some species can cause human discomfort, spread disease, and destroy food stores and crops, insects are often regarded as pests. This ignores the fact that the vast majority of insects cause little harm and play a crucial role in the world's environments. About three-quarters of all flowering plants rely on insects for pollination, and many animals depend on insects for food.

**Giant insect** About the size of a small rat, New Zealand's giant weta (*Deinacrida heteracantha*) can weigh up to 2½ ounces (70 g), making it among the heaviest of all insect species. The smallest insect, ranked in probably the parasitic wasp *Dicopomorpha echmepteryxis*, at [illegible] inch (0.14 mm) long.

## INSECT FLIGHT

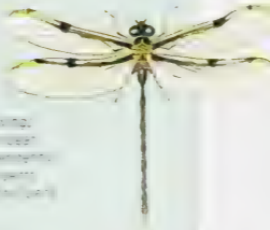
While some insects are wingless, the vast majority are winged as adults. Beetles and grasshoppers fly with a slow wing beat of 4–20 beats per second (bps) and limited maneuverability. Bees and true flies, with wing beats of about 190 bps, can hover and dart. Some midges have wing beats of 1,000 bps. The fastest sustained fliers are dragonflies, which can maintain speeds of 31 miles per hour (50 km/h).

***Folding wings*** The hindwings of a mantis fold up like fans when not in use. They protect the wings and allow the mantis to squeeze into tight spaces.

***Stabilizers*** True flies appear to have only one pair of wings; in fact, the second pair has been reduced to knob-like structures called halteres, that provide stability in flight.

***Plumed wings*** In moths and plume moths, the wings look like tiny feathers and are made up of fine hairs supported by a rib.

***Hooked wings*** Connected by tiny hooks, a wasp's forewings and hindwings move up and down in unison.



***Separate wings*** A dragonfly's forewings and hindwings beat at a rate of [illegible] movements. By [illegible] their flight [illegible] their [illegible].

***Protective wings*** [illegible]

# DRAGONFLIES AND DAMSELFLIES

PHYLUM Arthropoda
SUBPHYLUM Hexapoda
CLASS Insecta
ORDER Odonata
FAMILIES 30
SPECIES 5,500

The first members of the order Odonata emerged more than 300 million years ago—100 million years before dinosaurs appeared—and included the largest insect that has ever lived, a dragonfly with a wingspan of 28 inches (70 cm). Today's dragonflies and damselflies are much smaller, with wingspans from ¾ inch to 7½ inches (18 mm to 19 cm). Often seen flying near water, these voracious aerial predators are most abundant in the tropics, but can be found worldwide except for the polar zones. Damselflies have a fluttery flight and usually rest with the wings near the body, while dragonflies are strong, agile flyers and always rest with the wings held out from the body.

**Sharp sight** A dragonfly's large compound eyes may be made up of 30,000 lenses, providing superb vision and a wide field of view. Strong, biting mouthparts indicate the insect's carnivorous diet.

**Odonate aerobatics** With two pairs of large, veined wings that can beat together or independently, a dragonfly has great maneuverability and can hover and fly backward. Some species reach speeds of 20 miles per hour (30 km/h).

**Mating position** To mate, a male odonate grasps a female's head with claspers at the tip of his abdomen (below). The female will then bend her abdomen under the male to collect sperm from his sperm pouch.

## AQUATIC BEGINNINGS

A dragonfly or damselfly spends most of its life as a wingless aquatic nymph. The nymph breathes via gills and feeds on other insect larvae, tadpoles, and small fishes. It has a specialized lower mouthpart known as a mask that usually rests under its head but can shoot out to snatch prey in its pincers. Over a period of a few weeks to 8 years, depending on the species, the nymph may molt up to 17 times. For the final molt, it climbs out of the water and sheds its nymphal skin to reveal an adult with prominent eyes, sharp mouthparts, two pairs of transparent wings, a sloping thorax, and a long, slender abdomen.

A newly emerged adult dragonfly or damselfly flies away from water and starts to feed, snatching flying insects on the wing. To find mates, dragonflies will gather along a body of water, and males may engage in aerial contests. After mating, the male usually guards the female as she lays her eggs in the water. Most adults live for only several weeks.

# MANTIDS

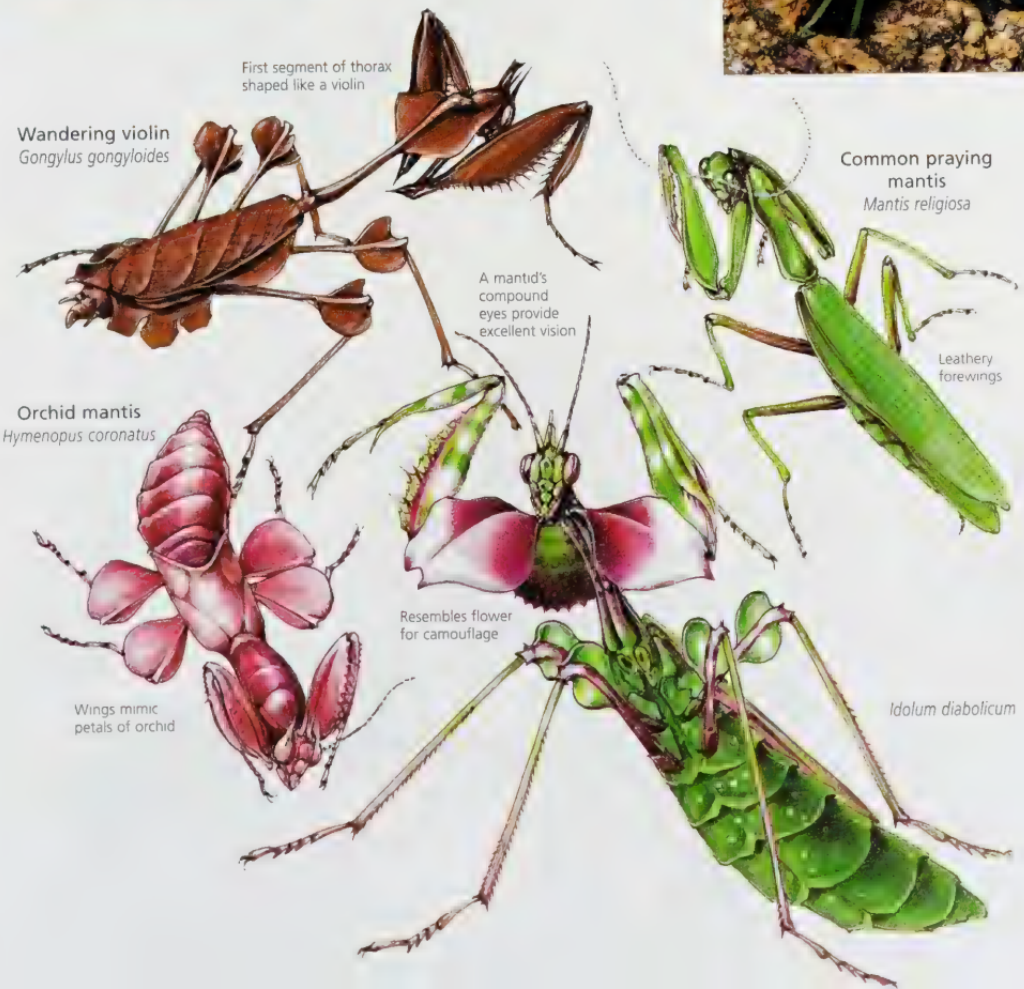
**PHYLUM** Arthropoda
**SUBPHYLUM** Hexapoda
**CLASS** Insecta
**ORDER** Mantodea
**FAMILIES** 8
**SPECIES** 2,000

Waiting to ambush prey, a mantid will sit perfectly still, holding its large forelegs folded up before it—a posture that inspired the common name of praying mantis for some species. With lightning-quick reflexes, the raptorial forelegs will shoot out to snatch insect prey. Most mantids are medium-sized, measuring about 2 inches (5 cm) long, but some tropical species reach lengths of 10 inches (25 cm). These giant mantids may add small birds and reptiles to their primarily insectivorous diet. While the majority of mantids live in the tropics or subtropics, some are found in the warm temperate areas of southern Europe, North America, South Africa, and Australia.

**Precision hunting** With its forward-facing eyes supplying binocular vision, a praying mantis has used its spiky, hooked forelimbs to impale a passing wasp. The mantis's strong mandibles quickly devour the meal

**Foaming protection** A female lays her eggs in a gummy fluid that she whips into a foam. When the foam hardens, it forms a case, or ootheca, that protects the eggs.

**Cannibalistic mating** In some mantid species, the transfer of sperm is more rapid if the female bites off the male's head. The male's self-sacrifice makes ecological sense as he is providing nourishment that will help his offspring survive.




## SILENT HUNTERS

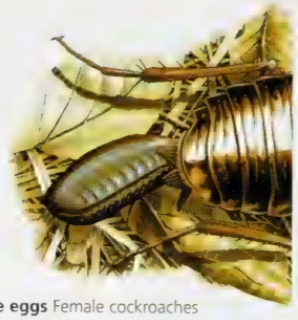
Mantids are masters at hiding from both predators and prey. They are the only insects that can turn their head without moving other parts of the body, allowing them to silently observe potential victims. Most species also have cryptic coloration that helps them blend in with the grass, leaves, twigs, or flowers of their environment. An alarmed mantid will adopt a threat posture, raising and rustling its wings and rearing up to show off its vivid warning coloration. Mantids that are targeted by bats at night possess a single "ear" on their thorax that can detect a bat's ultrasonic signals.

In some species, and especially in captivity, the female mantid will devour the male during copulation. Females mate only once, but from that single mating, they can produce up to 20 ootheca, or egg cases, each containing from 30 to 300 eggs. The young emerge from the ootheca as highly active nymphs, looking like miniature, wingless versions of their parents. Ready to hunt, they may even eat each other. The survivors disperse. After a series of molts, the nymphs mature and develop wings and adult coloration

# COCKROACHES

PHYLUM Arthropoda
SUBPHYLUM Hexapoda
CLASS Insecta
ORDER Blattodea
FAMILIES 6
SPECIES 4,000

As scavenging insects willing to feed on almost any plant or animal product, including stored food, trash, paper, and clothing, some cockroaches thrive in human environments and are widely regarded as repulsive pests. In fact, less than 1 percent of all cockroach species are pests—the remainder perform an important ecological role by recycling leaf litter and animal excrement in forests and other habitats. While most cockroaches are found in warm tropical zones, about 25 species have spread worldwide, accidentally transported on ships. Cockroaches are among the most primitive of all living insects, with an anatomy that has changed little in more than 300 million years.



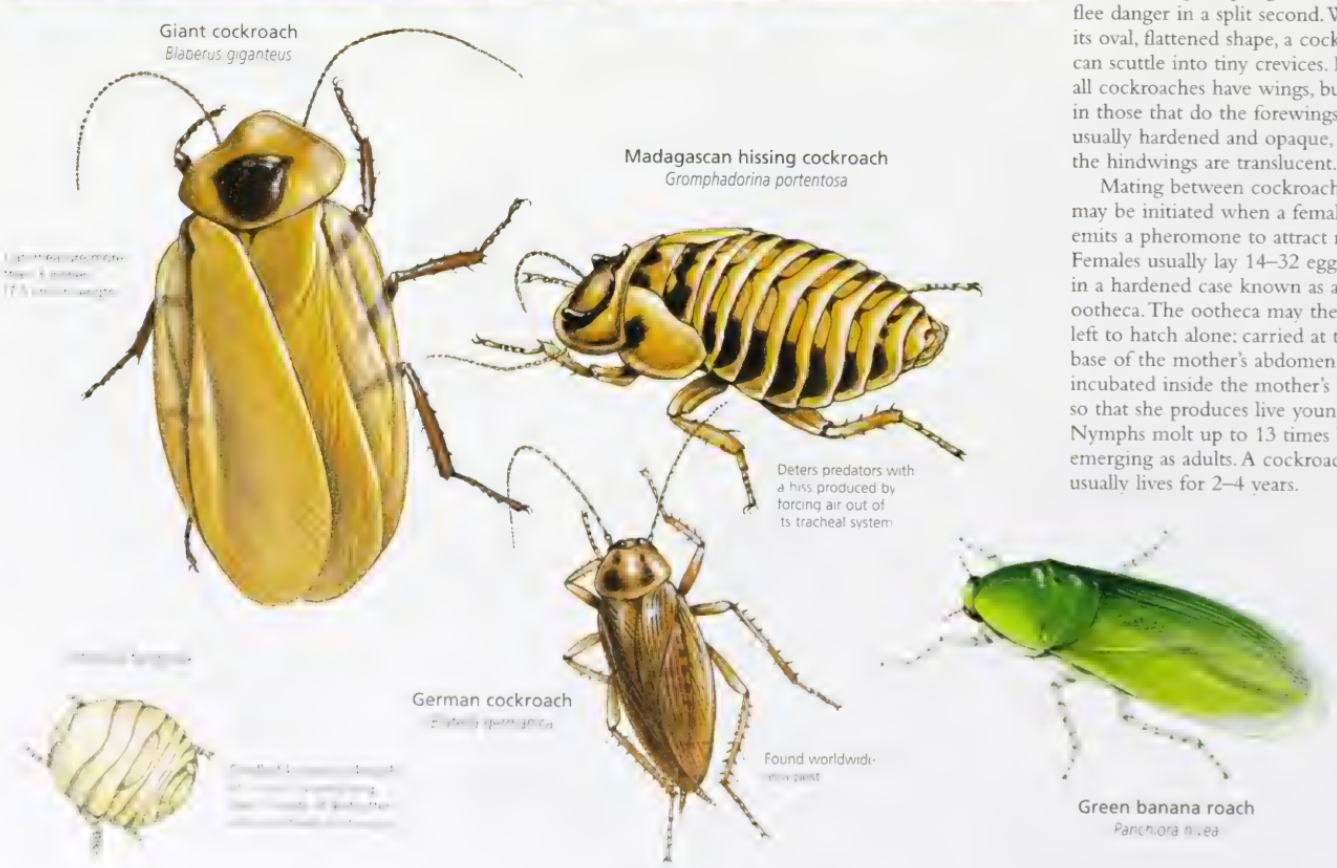
**Safe eggs** Female cockroaches deposit their eggs in an ootheca, or egg case. The nymphs emerge soft and white, but soon harden and turn brown They eat the ootheca as their first food

**Maternal care** Weighing up to 1¾ ounces (50 g), the giant burrowing cockroach (*Macropanesthia rhinoceros*) of Australia is the heaviest of all cockroaches. As many as 30 young are born alive and are fed by the mother in her burrow for up to 9 months

## SENSITIVE INSECTS

A range of sensors helps cockroaches to detect minute changes in their surroundings. Their long antennae can find minuscule amounts of food and moisture. Sensors on the legs and abdomen can pick up tiny air movements, prompting the insect to flee danger in a split second. With its oval, flattened shape, a cockroach can scuttle into tiny crevices. Not all cockroaches have wings, but in those that do the forewings are usually hardened and opaque, and the hindwings are translucent.

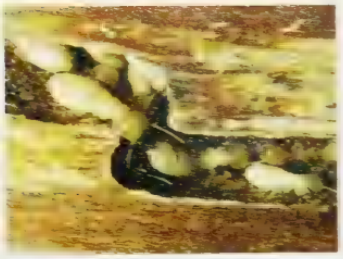
Mating between cockroaches may be initiated when a female emits a pheromone to attract males. Females usually lay 14–32 eggs in a hardened case known as an ootheca. The ootheca may then be left to hatch alone; carried at the base of the mother's abdomen; or incubated inside the mother's body so that she produces live young. Nymphs molt up to 13 times before emerging as adults. A cockroach usually lives for 2–4 years.



# TERMITES

**PHYLUM** Arthropoda
**SUBPHYLUM** Hexapoda
**CLASS** Insecta
**ORDER** Isoptera
**FAMILIES** 7
**SPECIES** 2,750

Termites may be the world's most monogamous animals. A king and queen mate for life, producing thousands or millions of offspring that operate together as a highly structured colony. These small insects are often referred to as white ants, but although their social system and anatomy resemble those of ants, they evolved independently and are most closely related to cockroaches. Found throughout much of the world, termites are most abundant in tropical rain forests, where there can be as many as 25,000 individuals per square mile (10,000 per sq km). By feeding on dead wood, they recycle nutrients in their natural habitats but can severely damage buildings in urban environments.



**Wood-eaters** With well-adapted guts that can digest tough wood, termites cause costly damage to buildings. Infestations often involve introduced species that have found a niche in the native environment.

**Egg-laying machine** A termite queen, shown here attended by other colony members, can grow 4½ inches (11 cm) long and produces 36,000 eggs a day from her enormous abdomen.

## CASTE SOCIETY

A mature termite colony has three castes: reproductives, workers, and soldiers. The main reproductives are the king and queen, who produce all the colony's other members and can live for 25 years. There may also be secondary reproductives ready to take over if the king or queen dies.

Workers and soldiers can be male or female. They are wingless, usually lack eyes and mature reproductive organs, and may live for 5 years. The pale and soft-bodied workers feed all other colony members and maintain the nest. Soldiers defend the colony, usually using powerful mandibles. Termite nymphs can develop into any caste, depending on the needs of the colony.

At a particular time each year, a swarm of winged males and females will emerge from a termite nest and disperse. They then shed their wings and form pairs, becoming the kings and queens of new colonies.

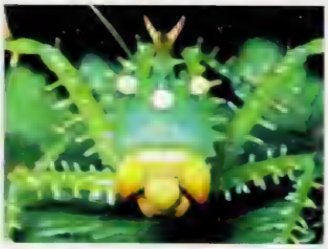
## INSIDE A NEST

Termite nests create a stable, humid microclimate sealed from the elements. While some termites nest inside wood, most construct subterranean nests that may rise partly above ground as mounds. Worker termites use saliva or feces to glue together particles of soil or wood, building a hard outer wall to protect the softer internal network of chambers.

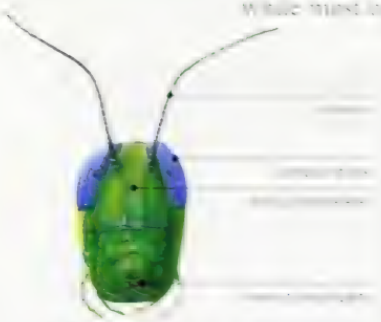
# CRICKETS AND GRASSHOPPERS

PHYLUM Arthropoda
SUBPHYLUM Hexapoda
CLASS Insecta
ORDER Orthoptera
FAMILIES 28
SPECIES > 20,000

Renowned for their songs and leaping ability, the members of the order Orthoptera include grasshoppers, locusts, crickets, katydids (or bush-crickets), and their kin. They are distinguished by elongated hindlegs that allow them to jump. Most species are winged, with slender, toughened forewings protecting the membranous, fan-shaped hindwings. While most orthopterans are ground-dwellers in grasslands and forests, some are arboreal, burrowing, or semiaquatic and species can be found in deserts, caves, bogs and marshes, and seashores. Grasshoppers, groundhoppers, and a few katydids are herbivores. While most other orthopterans are omnivorous.



**Threat display** Colored to match the vegetation of its Amazon rain-forest home, a spiky-headed katydid (Copiphora sp.) is covered in sharp spines and will rear up in a threat display to deter predators.

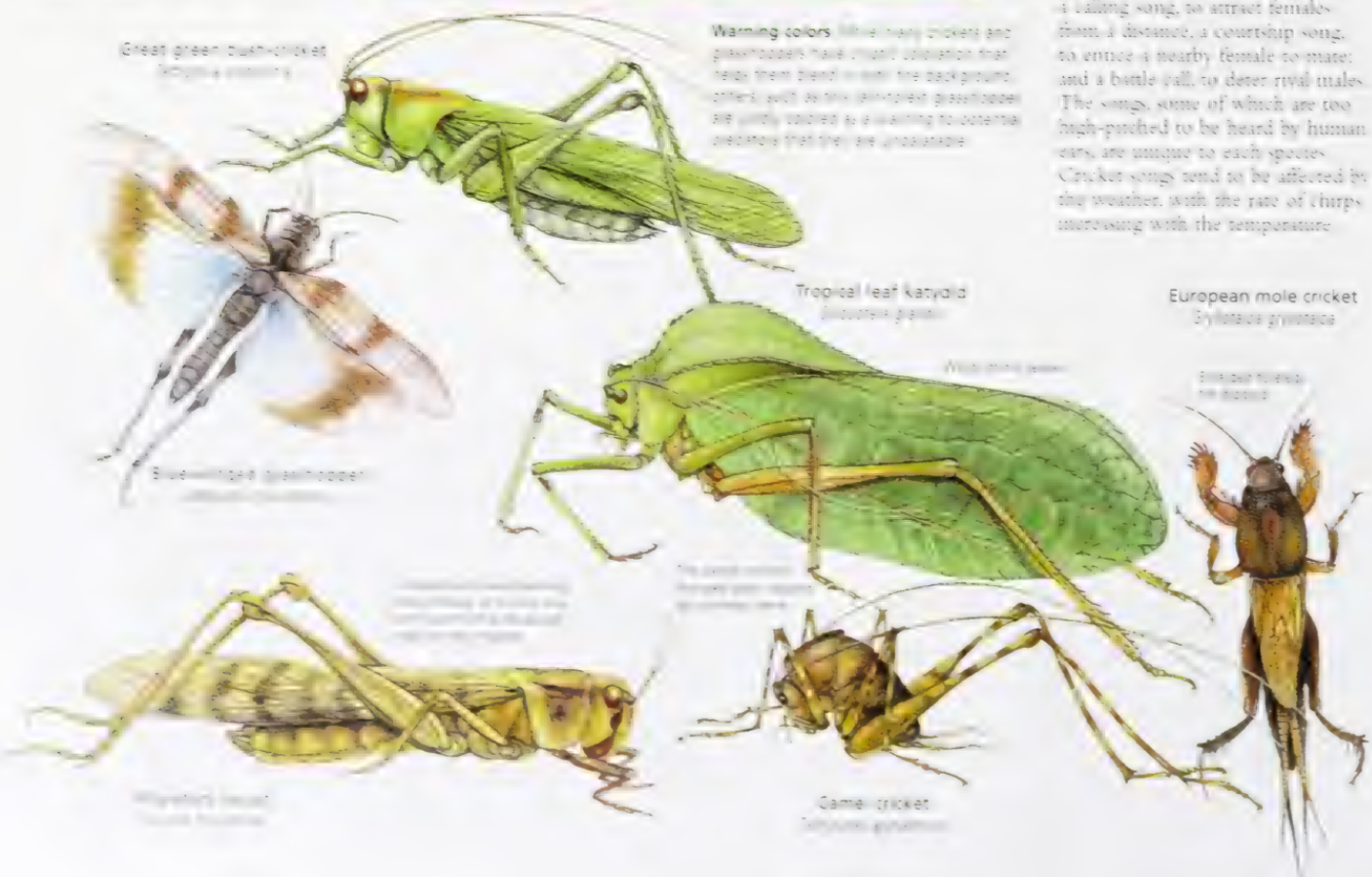


**Information collector** An orthopteran can hear, see, smell, and taste through antennae, which are used to navigate, locate food, and find a mate.

## SINGING INSECTS

Most male orthopterans can make sounds by rubbing two parts of the body together, a technique known as stridulation. Crickets and long-horned grasshoppers move a scraper on one forewing along a row of teeth on the other forewing, while short-horned grasshoppers rub a ridged surface on the hindleg against a forewing. The sounds can be heard by tympanal organs located on the legs or abdomen.

There are three kinds of song: a calling song, to attract females from a distance; a courtship song, to entice a nearby female to mate; and a battle call, to deter rival males. The songs, some of which are too high-pitched to be heard by human ears, are unique to each species. Cricket songs tend to be affected by the weather, with the rate of chirps increasing with the temperature.




**Warming colors** While many crickets and grasshoppers have insect coloration that helps them blend in with the background, others, such as this grasshopper, are vividly colored to a warning to potential predators that they are poisonous.

# BUGS

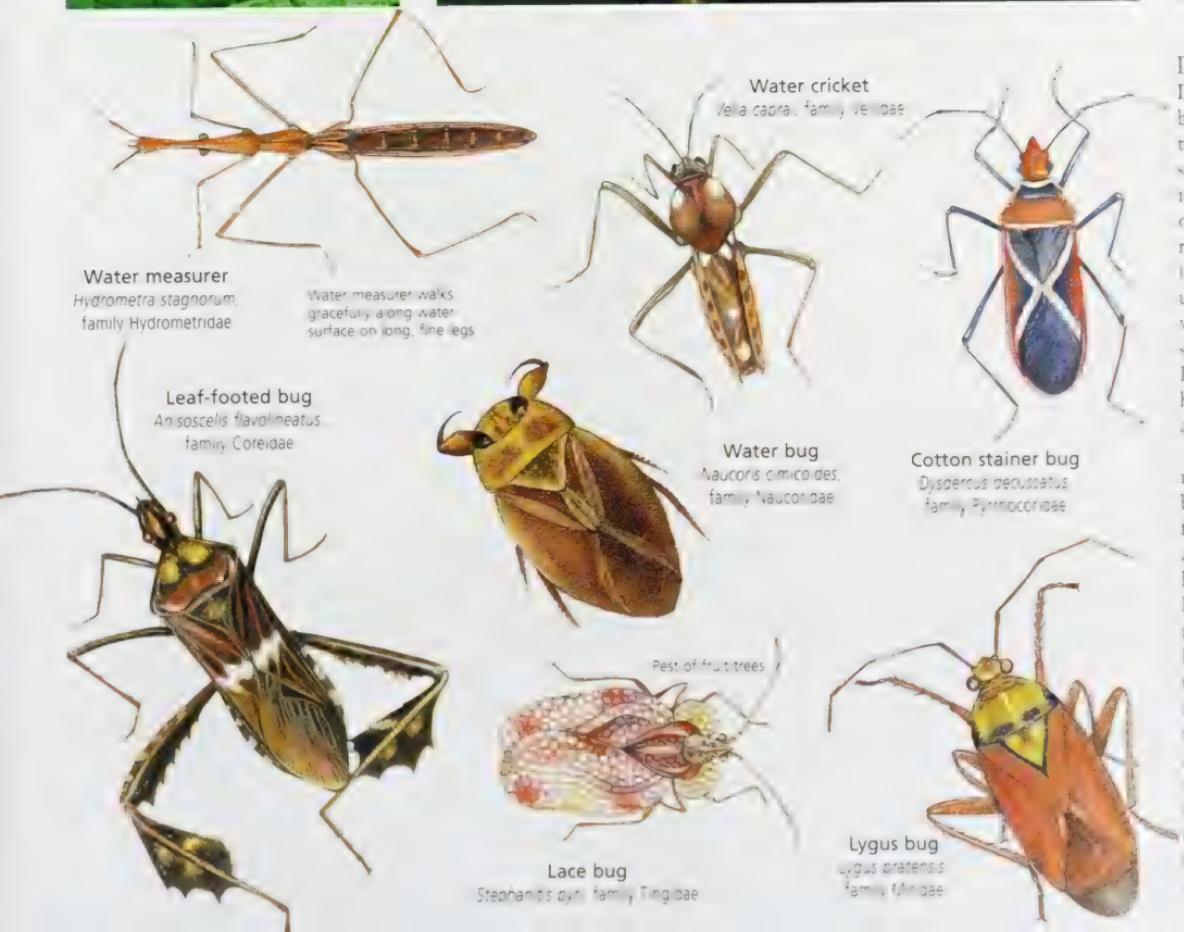
**PHYLUM** Arthropoda
**SUBPHYLUM** Hexapoda
**CLASS** Insecta
**ORDER** Hemiptera
**FAMILIES** 134
**SPECIES** > 80,000

Ranging from minute wingless aphids to giant frog-catching water bugs, the members of the order Hemiptera are extremely diverse. The name *Hemiptera* means "half wing," a reference to the fact that many, but not all, species have forewings that are leathery at the base and membranous at the tip. The one feature that all bugs have in common is their piercing and sucking mouthparts. With these, they pierce the surface of a plant or animal and inject saliva to start digesting the food, which they then suck into their mouth. Most bug species feed on plant sap, and some of these are significant agricultural pests. Other bugs suck the blood of vertebrates, or prey on other insects.

**Mimicry** In thornbugs, or treehoppers, the first plate of the thorax forms a thorn-shaped spine. This camouflages the insect as it sucks sap, and, even if an enemy does spot the insect, the spine deters an attack.

**Malodorous defense** The bright colors of many shield bugs serve to warn predators of the noxious odor produced when the insect is disturbed. Shield bugs are usually sap suckers, but a few are predatory.

**Predator bugs** While many bugs use their sucking mouthparts to feed on plant juices, others employ them to pierce live prey. This assassin bug lies in wait, ready to ambush an unwitting insect victim.




## DIFFERENT BUGS

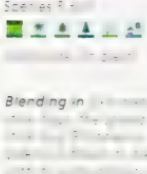
Distributed throughout the world, bugs can be found in almost all terrestrial habitats. Some species have specialized for an aquatic life—these include sea skaters (*Halobates* sp.), the only insects on the open ocean. Bugs range from [illegible] inch to 4[illegible] inches (1[illegible] mm to 11[illegible] cm) in length. They undergo incomplete metamorphosis, with nymphs that usually resemble small, wingless versions of the adults. In cicadas and some other species, however, the burrowing nymphs and the adults look quite different.

The order Hemiptera is divided into three suborders. In the true bugs (suborder Heteroptera), the forewings are toughened at the base and sit flat, concealing membranous hindwings. True bugs can flex their head and mouthparts forward, and many have stink glands. Cicadas and hoppers (Auchenorrhyncha) hold their uniform forewings over the abdomen like a roof. The head and mouthparts point down and back. Aphids, scale insects, mealybugs, whiteflies, and their kin all belong to the suborder Sternorrhyncha. Most have soft bodies kept moist by a covering of wax or mold. Wings are absent, absent or reduced to [illegible]

## FACT FILE

**Family Pentatomidae** Known as [illegible] bugs, [illegible] and shield bugs, [illegible] of the pungent liquid produced by their thoracic glands, the members of this family have a distinctive sage [illegible] shape to their body. Most [illegible] are plant suckers and many [illegible] agricultural pests.

Species [illegible]



*Blending in* [illegible]

**Family Reduviidae** This family contains the assassin bugs, predators that usually [illegible] other insects, but sometimes [illegible] the blood of vertebrates. The bugs [illegible] their curved proboscis forward to puncture the prey, and inject paralyzing saliva, then suck up the body fluids.

Species [illegible]

***Kissing bug*** *The conenose bug (Triatoma sanguisuga) is a blood-sucker. It is also called the kissing bug because it sometimes bites sleeping humans near the mouth.*

## PERIODICAL CICADAS

[illegible] in the [illegible] family Cicadidae, periodic [illegible] with [illegible] the [illegible] known as periodical cicadas [illegible] 13 years [illegible] 17 years [illegible] periodical cicadas are distinguished by their [illegible] development. After [illegible] underground, the [illegible] emerge in the same [illegible]

Red cicada
*Tibicen haematodes*
family Cicadidae

The hindwings of the peanut-headed lanternfly bear large spots that deter predators by mimicking the eyes of a larger animal

Peanut-headed lanternfly
*Laternaria phosphorea*,
family Fulgoridae

Peanut-shaped head

Lanternfly
*Laternaria candelaria*
family Fulgoridae

Treehopper
*Hemikyptha punctata*,
family Membracidae

Treehopper
*Bocydium globulare*, family Membracidae

Green shield bug
*Palomena prasina*,
family Pentatomidae

Bed bug
*Cimex lectuarius*, family Cimicidae

Bed bugs suck blood from vertebrates such as birds, cats, and humans

Large milkweed bug
[illegible]

Assassin bug
*Rhinocoris iracundus*, family Reduviidae

Squash bug
*Coreus marginatus*, family Coreidae

**European fruit lecanium**
*Parthenolecanium corni*, family Coccidae, superfamily Coccoidea

Adults protected by shiny brown domes

**Greenhouse whitefly**
*Trialeurodes vaporariorum*, family Aleyrodidae

Winged adult whiteflies are about 1 mm (1/25 in) long

Anal stage as a nymph is a scale-like case resembling a mealybug

Flat, oval nymphs are active crawlers on hatching, but soon become attached

**Woolly apple aphid**
*Eriosoma lanigerum*, family Aphididae

**Long-tailed mealy bug**
*Pseudococcus longispinus*, family Pseudococcidae, superfamily Coccoidea

Nymph and adult female long-tailed mealy bugs are protected by a white, waxy covering

**Nettle ensign scale**
*Ortheziola vallisi*, family Ortheziidae, superfamily Coccoidea

Adult

Nymph

**Apple leaf sucker**
*Psylla mali*, family Psyllidae

*Flata rubra*, family Flatidae

**Red and black froghopper (spittlebug)**
*Cercopis sanguinolenta*, family Cercopidae

Froghopper can leap to escape danger

Mimics thorn

**Treehopper**
*Heterocinetus reticulatus*, family Membracidae

*Euscelis plebejus*, family Cicadellidae

**Treehopper**
*Decoralia*, family Membracidae

## FACT FILE

**Family Aphididae** Aphids are tiny, soft-bodied plant-suckers that cause great damage to crops. They are able to rapidly increase their numbers by producing wingless or winged females from unfertilized eggs. In autumn, the winged females produce males and females that mate. The fertilized eggs lay dormant through winter and hatch in spring as females to begin the cycle again.

Species 2,000

Herbivore, on plants

**Cabbage aphid**
Native to Europe, the cabbage aphid *Brevicoryne brassicae* has spread to many parts of the world. It feeds on turnipseed and cultivated plants, causing serious damage to cabbage crops.

**Superfamily Coccoidea** Spending most of their life protected by a waxy secretion, the scale insects collected in this superfamily barely resemble insects at all. Adult females have sack-like wingless bodies and often lack legs and eyes. Adult males usually have wings and a more defined head, thorax, and abdomen, but lacking mouthparts, they cannot feed and are short-lived.

Species 7,500

Herbivore, on plants

**Well protected**
The cochineal scale *Dactylopius coccus* cannot crawl even as egg.

## APHIDS AS FOOD

Aphids provide food for many other insects. They are prey to many ants, beetles (family Coccinellidae), hoverflies (family Syrphidae), and lacewings (order Neuroptera). They are thought to maintain a mutualistic relationship with some species of ants, which protect them from predators and the elements in return for the ants' share of the aphids' honeydew, the sweet waste product of the animal's plant-sap diet.

Aphids (*Aphidoidea*) are a diverse group of small, soft-bodied insects. Many are wingless, but others have wings, as shown here.

# WATER INSECTS

Only about 3 percent, or 30,000, insect species are truly aquatic for at least part of their life-cycle. Water insects have had to adapt to the low oxygen content of water, as well as to the difficulty of moving about in still water or staying put in flowing water. Some insects, such as water striders, live only on the surface. Many, such as backswimmers, breathe air but carry it with them when they swim underwater. Others, such as dragonfly nymphs, spend all their time submerged, using gills to absorb oxygen from the water. The vast majority of aquatic insects live in fresh water, and only 300 or so species live in saltwater habitats, possibly because crustaceans evolved in the sea first and offer too much competition.

**Spinning swimmers** Whirligig beetles (family Gyrinidae) swim in small circles on the surface, using their flattened hindlegs like oars. They carry bubbles of air when they dive. Their eyes are split into two parts so they can see both above and below the water.

**Bubble breather** Predaceous diving beetles (family Dytiscidae) spend virtually their entire lives in water. The adults come to the surface to collect air, which they store in a bubble under their elytra (forewings). They swim using their hindlegs, which are fringed in thick hairs.

**Aquatic locomotion** Aquatic insects have evolved various strategies for moving around. Water scorpions (family Nepidae) can swim but often crawl along the bottom of a pond and spend much of their time hanging from pond weeds, waiting to ambush prey. They breathe air through a tube that sticks out above the surface. Water boatmen (family Corixidae) have long, hairy hindlegs that can "row" powerfully through the water. Water striders (family Gerridae) have fine hairs on their feet that allow them to make small jumps along the surface.

**Snorkelers** Mosquito larvae hang from the surface and filter plant matter from the water. While most aquatic larvae breathe through gills, mosquito larvae breathe air through a snorkel-like tube. This allows them to survive in pools of stagnant, oxygen-poor water.

**Aquatic predators** While many water insects are omnivores or plant-feeders, some, such as the predaceous diving beetles, are highly carnivorous. Even as larvae, diving beetles will tackle tadpoles, small fishes, and other prey larger than themselves. The adults use their powerful mandibles on substantial prey such as salamanders.

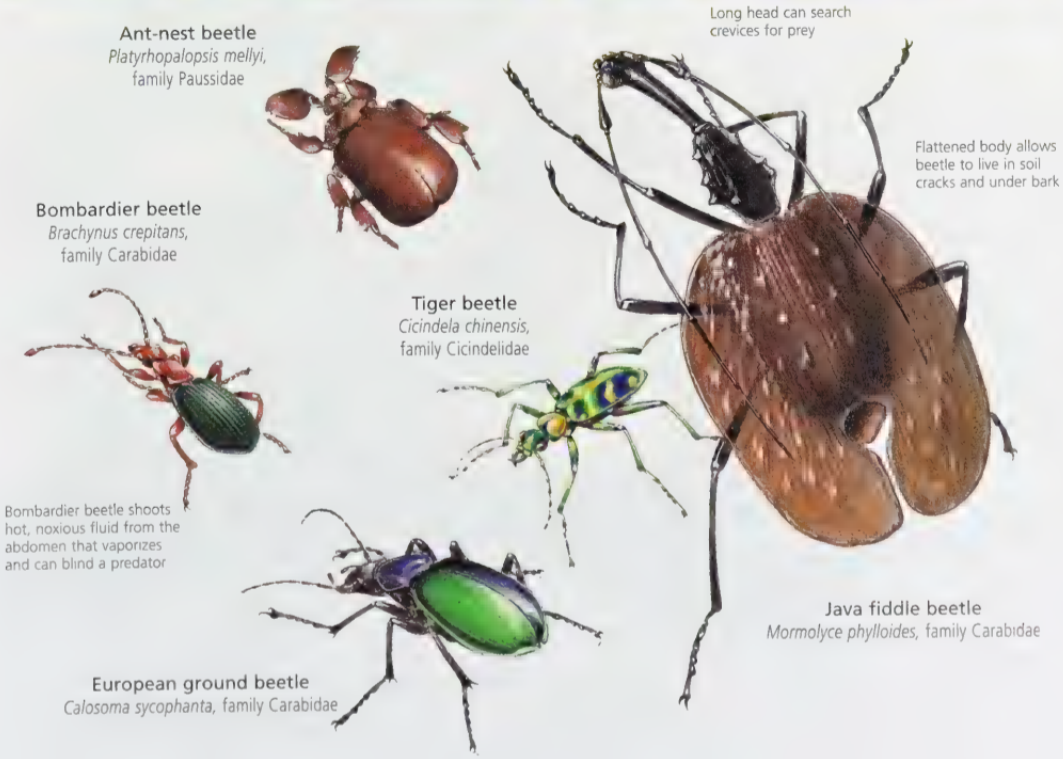
# BEETLES

**PHYLUM** Arthropoda
**SUBPHYLUM** Hexapoda
**CLASS** Insecta
**ORDER** Coleoptera
**FAMILIES** 166
**SPECIES** > 370,000

When asked what his study of the natural world had revealed about its Creator, the scientist J. B. S. Haldane replied, "an inordinate fondness for beetles." Of all known animal species, about one in four is a beetle. Members of the order Coleoptera have colonized almost all of Earth's habitats, from Arctic tundra and exposed mountaintops to deserts, grasslands, woodlands, and lakes. They reach their greatest diversity, however, in the lush rain forests of the tropics. Most beetles are distinguished by their hardened, leathery forewings, known as elytra, which protect the membranous, flying hindwings and allow the insect to live in tight spaces under bark or in leaf litter.

**Pollinating beetle** Although considered pests by many gardeners, spotted cucumber beetles (*Diabrotica undecimpunctata*) and many other beetles that eat pollen and foliage play an important role in helping to pollinate the plants on which they feed

**Competing males** The huge, branched mandibles of male stag beetles resemble a stag's antlers and perform a similar function, being used in competitions with rival males to win the right to mate. In some species, the mandibles are as long as the beetle




## DIVERSE FORMS

From lady beetles to diving beetles, scarab beetles to fireflies, the order Coleoptera encompasses enormous diversity. The feather-winged beetle (*Nanosella fungi*) is just 1/100 inch (0.25 mm) long, while the South American longhorn beetle (*Titanus giganteus*) can exceed 6½ inches (16 cm) in length. Adult beetles can be oval and flattened, long and slender, or squat and domed. While a few beetles are strong fliers, most are clumsy in flight, and some lack wings and cannot fly at all.

The mouthparts of beetles are all adapted for biting, but they have been put to many purposes. Plant-eating beetles may eat roots, stems, leaves, flowers, fruit, seeds, or wood. Carnivorous beetles usually attack invertebrate prey. A key ecological role is filled by scavenging beetles, which recycle dead animals and plants, excrement, and other waste.

Most beetles live on the ground, but some have specialized to live in trees, in water, and underground—a few even make their home in the nests of ants and termites

Beetles develop by complete metamorphosis, with larvae looking markedly different from the parents and going through a non-feeding, pupal stage before becoming adults

## FACT FILE

**Family Buprestidae** With spectacular colors and a metallic sheen, the jewel beetles in this family include some of the world's most attractive insects. They have a long oval body and are good fliers. Many adults feed on nectar, while larvae tend to be wood-borers.

Species [illegible]

Worldwide on plants

***Decorative wings*** The iridescent wings of North American metallic wood-boring beetle *Euphoria gigantea* are used in jewelry by local people.

**Family Coccinellidae** Also called ladybirds or ladybugs, the lady beetles of this family are among the best known of all insects. They are usually brightly colored and spotted, with a compact, rounded shape and short, clubbed antennae. Lady beetles are desired guests in gardens and farms. While a minority of species are plant-feeders, most lady beetles prey on aphids and other pests. A larva may eat 25 aphids a day, while an adult may eat as many as 50 aphids a day.

Species 5,200

Worldwide; on foliage

***Lines and spots*** *The convergent lady beetle* (*Hippodamia convergens*) is named after the converging white lines on the first segment of its thorax. It usually has 13 spots.

**Family Lampyridae** This family is made up of fireflies. All firefly larvae glow, producing light via a chemical reaction while giving off little heat. Their luminescence may be a warning to predators of their unpleasant taste. The larvae themselves are predaceous, following some trails to slugs and snails. Using organs on the abdomen, most adult fireflies also produce light, which they flash in a species-specific pattern to attract mates.

Species [illegible]

Worldwide; on [illegible]

***Aggressive mimic*** *Some female fireflies* [illegible]

European splendor beetle
*Anthaxia hungarica*,
family Buprestidae

Vivid color warns predators of lady beetle's foul taste

Seven-spotted lady beetle
*Coccinella septempunctata*,
family Coccinellidae

Larva of *Coccinella septempunctata*

Golden rove beetle
*Emus hirtus*
family Staphylinidae

Golden rove beetle is covered in fine hairs

Flesh-eating beetle
*Phosphuga atrata*, family Silphidae

Common carpet beetle
*Anthrenus scrophulariae*,
family Dermestidae

Feeds on carpet, wool, and other animal products

Glow worm
*Lampyris noctiluca*,
family Lampyridae

Water scavenger beetle
*Sphaeridium scarabaeoides*,
family Hydrophilidae

Winged male glow worms are attracted by the strong light emitted by wingless females

Larva of *Lampyris noctiluca*

European burying beetle
*Necrophorus vespillo*, family Silphidae

Buries corpses of small vertebrates as food for its young

Bee beetle
*Trichodes apiarius*,
family Cleridae

Parasitizes bee hives

Fuscous soldier beetle
*Cantharis fusca*, family Cantharidae

[illegible]

Can weigh up to 4 ounces (115 g), making it the heaviest of all insects

**Goliath beetle**
*Goliathus meleagris*, family Scarabaeidae

**Golden spider beetle**
*Niptus hololeucus*, family Ptinidae

**Spanish fly**
*Lytta vesicatoria*, family Meloidae

Caustic substance released by Spanish fly for defense has been considered a powerful aphrodisiac, but it is highly toxic and can be fatal in humans

**Black blister beetle**
*Meloe violaceus*, family Meloidae

Pest of stored organic materials including tobacco and museum specimens

**Cigarette beetle (tobacco beetle)**
*Lasioderma serricorne*, family Anobiidae

Male's horns can be longer than its body and are used in contests with rivals

**Hercules beetle**
*Dynastes hercules*, family Scarabaeidae

**Rhinoceros dung beetle**
*Oxysternon conspicillatum*, family Scarabaeidae

Two spots on thorax and one on abdomen produce the brightest bioluminescence in the insect world

**Fire beetle**
*Pyrophorus noctilucus*, family Elateridae

**Green scarab**
*Eudicella gralli*, family Scarabaeidae

## FACT FILE

**Family Meloidae** When disturbed the blister beetles in this family release a caustic, toxic fluid from their joints that can cause blistering in human skin. Most adults feed on flowers and foliage. The larvae, however, tend to be specialized predators, with some species living in bee hives and eating the eggs, larvae, and stored food of the bees

**Species** 2,500

Worldwide; on plants

***Distinctive form*** *Blister beetles such as* Cerocoma muehlfeldi *have a soft, slender body with long legs*

**Family Elateridae** This family comprises the click beetles. If a click beetle ends up lying upside down, it will straighten its back and propel itself into the air to land right way up. As it does so, a hinge-like structure on the elytra makes a loud click. Adults feed on foliage, while the yellow or brown larvae live in soil and eat roots and bulbs

**Species** 9,000

Worldwide; near plants and in soil

***Groovy wings*** *Like other click beetles,* Semiotus distinctus *has a long, slender body with grooved elytra*

## BEETLE LIFECYCLE

All beetles develop through complete metamorphosis. In most species, eggs are fertilized sexually, although a few beetles lay unfertilized eggs without mating. The eggs hatch into a larva that has chewing mouthparts but otherwise bears little resemblance to the adult it will become. The larva molts several times, growing larger until it is ready to pupate. Enclosed in a cocoon, the larva transforms into a pupa with adult features. It is soft and pale when it emerges but soon hardens and colors, now an adult that is ready to reproduce

## FACT FILE

**Family Lucanidae** This family contains stag beetles. Much larger than the [illegible] stag beetles are further [illegible] by their huge mandibles. Males will use their mandibles in [illegible]. Larvae feed on dead or rotting wood and may take several years to mature. Some adults eat leaves, but most feed on nectar.

Species [illegible]

[illegible] worldwide, in trees

*South American stag* [illegible]

**Family Curculionidae** Sometimes called snout beetles, weevils constitute Curculionidae, the largest of all families in the animal kingdom. A prominent snout carries biting mouthparts and is used for feeding on with plants and boring holes in plants, seeds, fruit, or soil for to eggs. Usually longest on females, the snout can be much longer than the body in some species. Some weevil species are serious agricultural pests.

Species [illegible]

[illegible] worldwide, near plants

*Shimmering weevil* [illegible]

**Family Cerambycidae** Known as longhorn or longicorn beetles, the members of this family have long, narrow bodies, which range in length from [illegible] millimetres (0.[illegible] inch) to the largest species. [illegible] antennae. [illegible] as long as their bodies. The antennae are used for finding mates, as a [illegible], [illegible], and to [illegible] on living and dead trees.

Species [illegible]

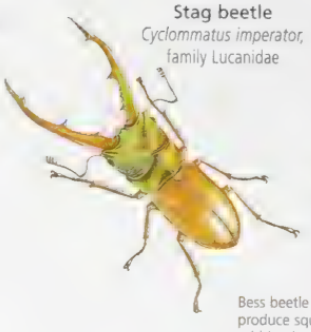
[illegible] worldwide, [illegible]

*Longhorn in danger* [illegible]

Larva of Leptinotarsa decemlineata

Serious pest of potato crops

**Colorado potato beetle**
*Leptinotarsa decemlineata,*
family Chrysomelidae



**Stag beetle**
*Cyclommatus imperator,*
family Lucanidae

**Bess beetle**
*Proculus goryi,*
family Passalidae

Bess beetle larvae and adults produce squeaking sound by rubbing body parts together

Female acorn weevil bores into acorns and nuts to lay eggs

**Acorn weevil**
*Curculio nucum,* family Curculionidae

Male's hindlegs much larger than female's

**Frog-legged leaf beetle**
*Sagra buqueti,* family Chrysomelidae

Male harlequin beetle uses his extremely long legs to attract mates

**Harlequin beetle**
*Acrocinus longimanus,* family Cerambycidae

**Large elm bark beetle**
*Scolytus scolytus,* family Scolitidae

Beetle's galleries produce distinctive pattern on bark of elm trees

Large elm bark beetle spreads the fungus that causes Dutch elm disease

Declining in Europe as its oak-tree habitat disappears

**Great capricorn beetle**
*Cerambyx cerdo,*
family Cerambycidae

**Turnip flea beetle**
*Phyllotreta nemorum,*
family Chrysomelidae

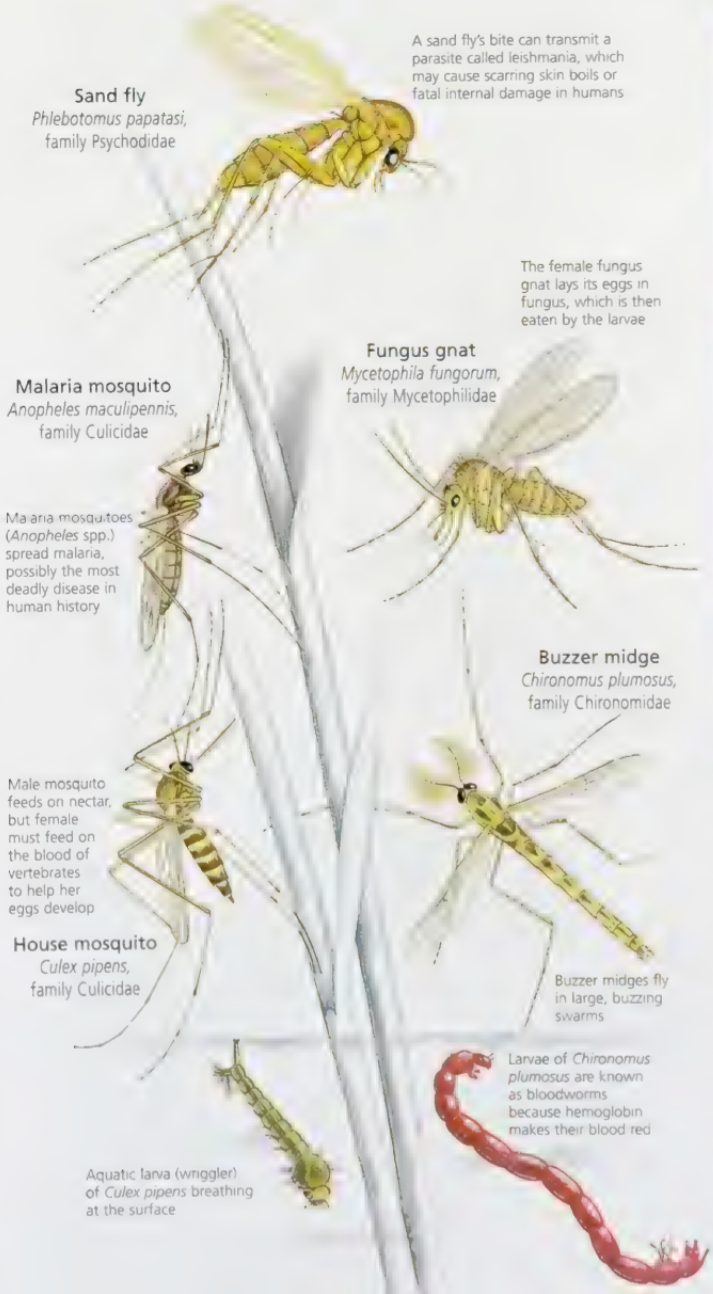
**King weevil**
*Gymnopholus weiskei*
family Curculionidae

# FLIES

**PHYLUM** Arthropoda
**SUBPHYLUM** Hexapoda
**CLASS** Insecta
**ORDER** Diptera
**FAMILIES** 130
**SPECIES** 120,000

Houseflies and mosquitoes are the most ubiquitous members of the order Diptera, which also includes gnats, midges, blowflies, fruit flies, crane flies, horseflies, hover flies, and other true flies. While most insects fly with four wings, dipterans are generally distinguished by their single pair of functional wings. The hindwings are reduced to halteres, tiny clubbed stalks that vibrate up and down in time with the forewings, helping the fly to balance during flight. Some species have lost their wings altogether and are flightless. Although often associated with moist environments and decaying matter, flies live almost everywhere in the world except Antarctica.

**Eyes and wings** Mostly active by day, flies rely on their large compound eyes, each with up to 4,000 lenses. The first segment of the thorax is enlarged to hold the huge muscles that propel the forewings.



**Daddy long legs** Crane flies make up Tipulidae, the largest family of flies. Adults have mosquito-like bodies with very long legs. They often feed on nectar in humid forests. Larvae live in moist soil or water.

## STICKY SUCKERS

Flies are small insects, ranging from midges ½ inch (1 mm) in length, to robber flies about 3 inches (7 cm) long. Their feet have sticky pads with tiny claws, allowing the insects to walk on smooth surfaces, even upside down along a ceiling.

With mouthparts designed for sucking, flies can consume only liquid food. Houseflies have fleshy pads on their mouth that can sponge up a meal. Mosquitoes have piercing mouthparts for feeding on nectar and blood. Robber flies use their mouthparts to stab insect prey.

Flies begin life as eggs, from which larvae hatch. Often known as maggots, the larvae usually [illegible] pale, soft bodies and lack true legs. After several molts, they pupate into the adult form.

Their feeding habits, abundance, and wide distribut[illegible] flies responsible for th[illegible] deadly diseases such a[illegible] sleeping sickness. They [illegible] ecological roles [illegible] decomposers of organic [illegible] as links in the food chain.

## FACT FILE

**Family Syrphidae** The hover flies of this family will hover in one spot, then dart forward or sideways before hovering again. With their black and yellow abdomen and habit of feeding on nectar, they resemble bees or wasps, but do not bite or sting. The larvae of many hover-fly species are welcome in gardens because they eat aphids

Species 6,000

Worldwide; on flowers

***Pollinating pest*** *The narcissus fly (Merodon equestris) is considered a pest because its larvae eat plant bulbs, but, like other hover flies, the adults are important pollinators*

**Family Tabanidae** The stout flies in this family are known as horseflies or deerflies. While the males feed on nectar, honeydew, and sap, the females are bloodsuckers because they need protein to develop their eggs. Females use their blade-like mouthparts to slice through the skin of mammals so they can suck up the blood

Species 4,000

Worldwide; near mammals

***Common names*** *Like other species in its genus, Chrysops caecutiens is usually known as a deerfly. Species in the genus Tabanus tend to be called horseflies*

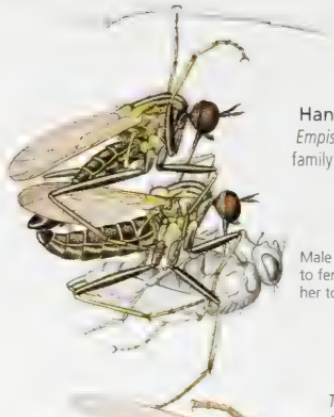
## FLIGHTLESS FLIES

In several families of flies, some species have lost their wings and do not fly. The family Tipulidae (crane flies) includes the flightless snow fly (*Chionea* sp.), which remains active throughout the winter in its snow-covered habitat. Able to tolerate temperatures of 20°F (−6°C), it avoids the many predators that appear in warmer months. Since flight requires warmer muscles than possible in this environment, the [illegible] fly has discarded its wings. The [illegible] however, have been retained

***Wingless parasite*** *The bee louse (Braula caeca) from the family Hamaemyiidae is a [illegible] its [illegible]*

Resembles bumblebee but has larger eyes and smaller antennae

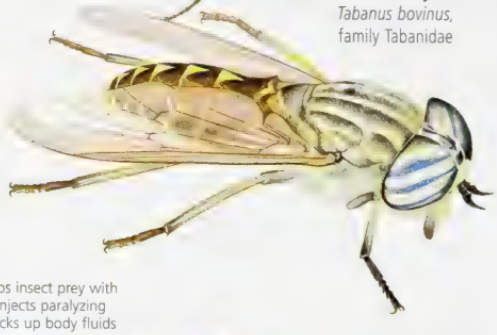
**Bumble fly (hover fly)**
*Volucella bombylans*, family Syrphidae



Male offers prey to female to entice her to mate

**Hanging fly**
*Empis tesselata*, family Empididae

**American fruit fly**
*Rhagoletis pomonella*, family Tephritidae



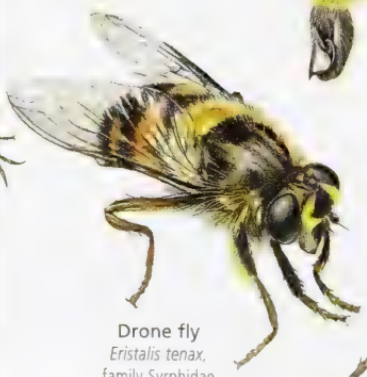
**Horsefly**
*Tabanus bovinus*, family Tabanidae

Robber fly stabs insect prey with its proboscis, injects paralyzing saliva, then sucks up body fluids

**Robber fly**
*Laphria flava*, family Asilidae

**Greater bee fly**
*Bombylius major*, family Bombyliidae

Parasite of ground-nesting bees



**Drone fly**
*Eristalis tenax*, family Syrphidae

Soldier fly resembles wasp in appearance and behavior but does not sting

**Soldier fly**
*Stratiomys chamaeleon*, family Stratiomyidae

**Hover fly**
*Syrphus ribesii*, family Syrphidae

Eyes on the end of long stalks may enhance stereoscopic vision or may simply advertise a male's genetic health to prospective mates

**Stalk-eyed fly**
*Diopsis tenuipes*, family Diopsidae

Pest in cheeses and cured meats

**Cheese skipper**
*Piophila casei*, family Piophilidae

Gout fly larvae live inside the stems of cereal crops, causing a gouted appearance

**Gout fly**
*Chlorops pumilionis*, family Chloropidae

**Mantis fly**
*Ochthera mantis*, family Ephydridae

Mantis fly adults and larvae prey on ground-dwelling spiders and their eggs

**Latrine fly**
*Fannia scalaris*, family Fanniidae

Female latrine fly lays eggs in feces of humans and animals

**Stable fly**
*Stomoxys calcitrans*, family Muscidae

Tsetse fly sucks the blood of large mammals and spreads the fatal sleeping sickness trypanosomiasis to humans and livestock in Africa

**Tsetse fly**
*Glossina palpalis*, family Glossinidae

**Sheep nasal botfly**
*Oestrus ovis*, family Oestridae

Female sheep nasal botfly deposits hatched larvae near the nostrils of sheep and goats so they can feed on the mucus

**Yellow dung fly**
*Scatophaga stercoraria*, family Scatophagidae

Larvae of yellow dung fly eat dung, while the adults prey on other flies that visit dung to feed

**Beet fly**
*Pegomya betae*, family Anthomyiidae

**Tachinid fly**
*Tachina fera*, family Tachinidae

After female horse botfly lays eggs in a horse's coat, the larvae hatch, move to the horse's mouth, and then develop in its stomach for up to a year; they are then passed into the feces and the adults emerge soon after

**Horse botfly**
*Gasterophilus intestinalis*, family Gasterophilidae

**Common housefly**
*Musca domestica*, family Muscidae

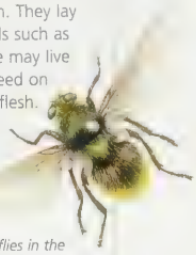
**Sheep blowfly**
*Lucilia sericata*, family Calliphoridae

## FACT FILE

**Family Oestridae** The adult botflies in this family lack functional mouthparts and do not feed, spending their short lives solely on reproduction. They lay their eggs on live mammals such as sheep and deer. The larvae may live in the host's nostrils and feed on mucus, or burrow into its flesh.

**Species** 70

Worldwide; near sheep, goats & deer



***Fast flyers*** *The deer nose botflies in the genus* Cephenemyia *are among the swiftest of all insects, flying at speeds of up to 50 miles per hour (80 km/h)*

**Family Calliphoridae** Usually characterized by a loud, buzzing flight, the blowflies in this family have stout, bristly bodies with a metallic sheen They lay their eggs in carrion so that the larvae can feed on the decaying flesh, giving the meat a blown-up appearance that inspired the common name of *blowfly*.

**Species** 1,200

Worldwide; near carrion & meat

***Live feeder*** *The larvae of the European bluebottle blowfly (*Calliphora vicina*) can infest open wounds in livestock and humans.*

### FLIES AS CLUES

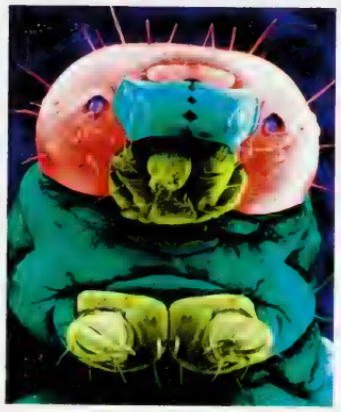
Forensic entomologists can analyze the fauna living on a corpse to determine time of death and other information. Carrion-feeders arrive in a predictable succession. Houseflies and blowflies are usually the first to turn up. They lay their eggs in the flesh, and the larvae then hatch and develop. Their stage of development can reveal how long the corpse has been dead. Flesh flies arrive later. When the corpse has dried out, some months after death, cheese skippers (family Piophilidae) and coffin flies (family Phoridae), along with mites and beetles, pick clean the skeleton

***Flesh-feeder*** *Flesh flies (family Sarcophagidae) will colonize a corpse later than houseflies and blowflies, but catch up by depositing live larvae rather than eggs*

# BUTTERFLIES AND MOTHS

PHYLUM Arthropoda
SUBPHYLUM Hexapoda
CLASS Insecta
ORDER Lepidoptera
FAMILIES 131
SPECIES 165,000

With their delicate fluttering flight and often intricate wing patterns, butterflies and moths are the most studied and admired of all insects. They belong to the order Lepidoptera, which means "scale wing" in Greek. Their four broad wings are covered by tiny, overlapping scales—hollow, flattened hairs that create the bright colors and iridescence of diurnal species. Almost all butterflies and moths are plant-feeders. Their larvae, known as caterpillars, have biting mouthparts for chewing plants, which can make them pests. Most adults have a long proboscis for sucking flower nectar and are important pollinators, though a few lack mouthparts and do not feed at all.



**Plant muncher** A caterpillar is an eating machine, with biting mouthparts for munching through foliage or other plant food. Many species are brightly colored to warn predators that they are unpalatable

**Nectar-feeder** [illegible]

European pine shoot moth
[illegible]

Bird-cherry ermine
[illegible]

Meal moth
*Pyralis farinalis*, family Pyralidae

Carpet moth (tapestry moth)
[illegible]

Moths usually rest with their wings apart or held like a roof over the abdomen, while most butterflies rest with their wings together in a vertical position

Longhorn moth
[illegible]

Codling moth
*Cydia pomonella*, family Tortricidae

## DAY AND NIGHT FLYERS

Absent only from the polar ice caps and the oceans, butterflies and moths are most abundant in the tropics but are found virtually anywhere that land plants grow. Most are highly specialized for feeding on particular flowering species.

As adults, butterflies and moths have slim bodies, broad wings, long antennae, and two large compound eyes. Their wingspans range from about 3/16 inch to 12 inches (4 mm to 30 cm). More than 85 percent of species in Lepidoptera are moths, most of which fly at night and have dull wings that are coupled by a spine-like structure known as a frenulum. Butterflies fly by day, display vibrant colors, have clubbed antennae, and lack the frenulum. Some moth species, however, are also diurnal and brightly colored.

Caterpillars are covered in hairs, and walk using three pairs of true legs and several false legs. When ready to pupate, they usually enclose themselves in a cocoon or chrysalis, using silk from modified salivary glands. The entire life-cycle takes from a few weeks to a few years.

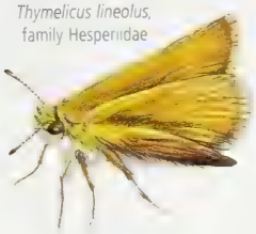
### CONSERVATION WATCH

**Deadly trade** Only 303 lepidopterids have been assessed by the IUCN, but of these, 94 percent are on the Red List and 37 are extinct. Habitat loss is the major cause of the decline, but over-collecting has also had a major impact on attractive species such as the birdwing butterflies.

Bent-wing ghost moth
*Zelotypia stacyi*, family Hepialidae

Hornet clearwing
*Sesia apiformis*, family Sesiidae

Mimics stinging hornet to deter predators



Essex skipper
*Thymelicus lineolus*, family Hesperiidae

Owl moth
*Xyleutes strix*, family Cossidae

Provence burnet moth
*Zygaena carniolica*, family Zygaenidae

Garden tiger moth
*Arctia caja*
family Arctiidae

Goat moth is named after the goaty odor of its wood-burrowing caterpillar



Goat moth
*Cossus cossus*, family Cossidae

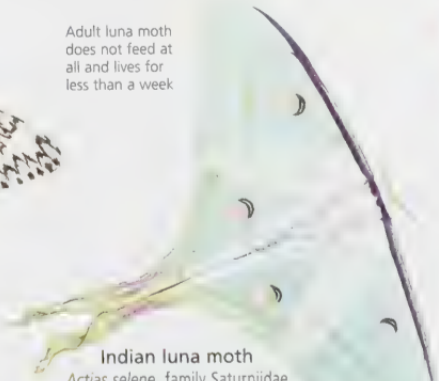
Adult garden tiger moth has striped abdomen; caterpillar is covered in thick, dark hairs and is commonly known as a "woolly bear"

Adult luna moth does not feed at all and lives for less than a week

Larvae of *Gastropacha quercifolia*

Lappet
*Gastropacha quercifolia*
family Lasiocampidae

Nun moth
(black arches moth)
*Lymantria monacha*,
family Lymantriidae



Indian luna moth
*Actias selene*, family Saturniidae

Eyespots on hindwings startle predators; forewings mimic dead leaves

Eyed hawk moth
*Smerinthus ocellatus*, family Sphingidae

Largest wing surface area of any moth in the world

Giant atlas moth
*Attacus atlas*, family Saturniidae

## FACT FILE

**Family Hepialidae** The most primitive family, are known as ghost moths or swift moths. The adults lack functional mouthparts and cannot feed, spending all their time on reproduction. As they fly, females release enormous quantities of eggs, with some species depositing up to 30,000 eggs. The larvae tend to hatch in soil and feed on roots, although some species feed on leaves, grasses, moss, and wood.

Species 500

Worldwide except N. Africa & Madagascar; near plants

***Contrasting sexes***
Found in Australia's rain forests, the female ghost moth, *Aenetus virescens*, is green, while the male is white.

**Family Sesiidae** The clear-winged moths in this family lose most of their scales so that their wings are largely transparent. Along with yellow and brown stripes on the abdomen, the clear wings help many species mimic stinging insects such as bees, wasps and hornets. Many larvae bore into stems and roots.

Species 1,000

Worldwide; near flowers

***Currant borer***
The larvae of the currant clearwing (*Synanthedon tipuliformis*) are considered pests because they bore into the stems of currant or gooseberry bushes to feed.

**Family Hesperiidae** The members of this family are known as skippers or darters because they rapidly flit from flower to flower. They are considered to be an intermediate form between butterflies and moths. They generally have drab colors, and solid, heavy bodies that resemble those of moths, but the lack of the wing-coupling structure found in most moths suggests affinity with the wings held vertically.

Species 3,000

Worldwide except the coldest regions; near flowers, especially grasses

***Hooked antennae***
[illegible]

## FACT FILE

**Family Papilionidae** Often large and brightly colored, the swallowtails of this family are named after the tail-like extensions on the hindwings of most species. All swallowtail caterpillars have an osmeterium, a fork-shaped organ on their head that can release a foul odor to deter a predator. In some species, the caterpillars feed on poisonous plants, absorbing enough toxins to make both themselves and their adult form unpalatable.

Species [illegible]

Worldwide, near flowers

***Vivid warning*** The bright wing markings of the common rose, *Pachliopta hector*, and many other swallowtails warn predators that they have an unpleasant taste.

**Family Noctuidae** Noctuid or owlet moths make up the largest family in the order Lepidoptera. These night flyers have hearing organs on their thorax that can pick up echolocation signals emitted by bats, their main predators. Adults feed on nectar, sap, rotting fruit, tears, or dung, while the larvae may eat foliage or seeds, or bore into stems and fruit, with some being serious crop pests.

Species [illegible]

Worldwide, on plants

***Background colors*** Like many noctuid moths, *Mormo maura* has cryptic camouflage. The mottled wings blending in with the surrounding bark.

**Family Geometridae** Known as geometer, looper, or inchworm moths, the members of this family tend to be small, with slender bodies. The larvae, which often resemble twigs when resting, lack at least one middle pair of false legs. They move by stretching out the front part of the body, then bringing the tail forward to meet it, creating a "looping" or "inching" gait.

Species [illegible]

Worldwide, on trees

***Leaf mimic*** [illegible]

**Moth butterfly**
*Liphyra brassolis*, family Lycaenidae

Caterpillars of moth butterfly feed on larvae of citrus ants and have tough skin that protects them from the ants' bites

**African giant swallowtail**
*Papilio antimachus*, family Papiolinidae

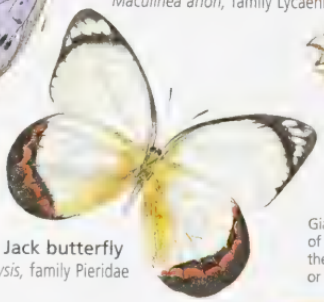
African giant swallowtail is the largest of all African butterflies, with a wingspan of 10 inches (25 cm) or more

**Orange-barred sulphur**
*Phoebis philea*, family Pieridae

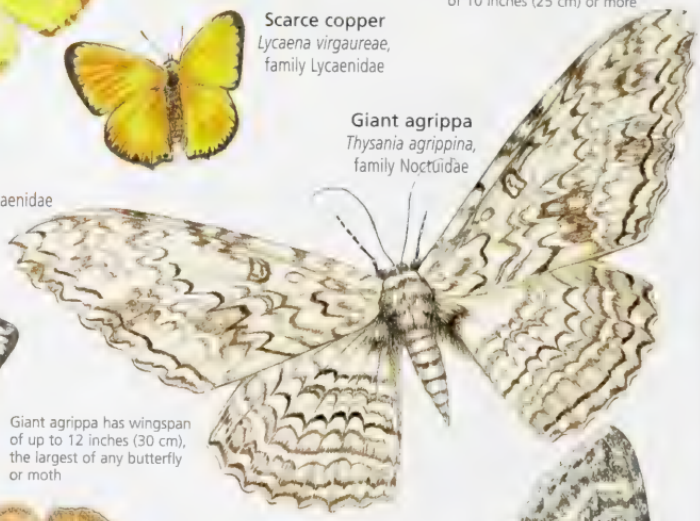
**Cabbage butterfly**
*Pieris brassicae*, family Pieridae

**Scarce copper**
*Lycaena virgaureae*, family Lycaenidae

**Large blue**
*Maculinea arion*, family Lycaenidae

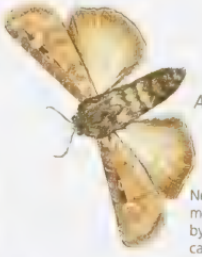


**Union Jack butterfly**
*Delias mysis*, family Pieridae



**Giant agrippa**
*Thysania agrippina*, family Noctuidae

Giant agrippa has wingspan of up to 12 inches (30 cm), the largest of any butterfly or moth



**Bogong moth**
*Agrotis infusa*, family Noctuidae

Newly emerged adult bogong moths avoid the summer heat by migrating to mountain caves and becoming dormant until autumn, when they return to the plains to breed

**Bhutan glory butterfly**
*Bhutanitis lidderdalii*, family Papilionidae

**Apollo butterfly**
*Parnassius apollo*, family Papilionidae

**Red underwing moth**
*Catocala nupta*, family Noctuidae

Only male mottled umbers fly; females are wingless

**Mottled umber**
*Erannis defoliaria*, family Geometridae

Large eyespot on hindwing deters predators

Adult owl butterfly feeds on rotting fruit

**Owl butterfly**
*Caligo idomeneus,*
family Nymphalidae

**The postman**
*Heliconius melpomene,*
family Nymphalidae

♂

All Helena butterflies have yellow-brown wings, but, on the males, air spaces between the scales scatter light and produce blue iridescence

**Helena butterfly**
*Morpho rhetenor,* family Morphidae

♀

Patches on underside of wings mimic holes and other blemishes found on dead leaves

**Silver-washed fritillary**
*Argynnis paphia,*
family Nymphalidae

**Dead leaf butterfly**
*Kallima inachus,*
family Nymphalidae

*Kallima inachus* in flight

**Northern jungle queen butterfly**
*Stichophthalma camadeva,*
family Nymphalidae

Female mimic is palatable but imitates the unpalatable African monarch to discourage predators

**African monarch (lesser wanderer)**
*Danaus chrysippus,*
family Nymphalidae

♂

Male mimic [illegible] on ground for [illegible] and is [illegible] with the [illegible]

**Mimic**
*Hypolimnas misippus,*
family Nymphalidae

♀

## FACT FILE

**Family Nymphalidae** Known as brush-footed butterflies, the species in this family have very small and hairy forelegs, and walk using only the middle and back legs. The underside of the wings tends to be drab, while the upperside usually features strongly contrasting colors

**Species** 5,200

Worldwide, near flowers

***Seasonal variation*** *The map butterflies (Araschnia levana) that emerge in spring have orange-marked wings, while those that emerge in summer are black and white*

## COCOONS AND CHRYSALISES

When they are ready to transform into adults, caterpillars stop eating and find a safe spot. Some pupate underground without any further protection, but most moths spin a cocoon of silk, while almost all butterflies create a chrysalis, a hard shell formed from the caterpillar's skin and secured by silk to a branch

***Sticky cocoon*** *The larvae of bagworm moths (Thyridopteryx ephemeraeformis) live in cases of silk and plant debris, which harden into cocoons when they are ready to pupate*

***Transforming chrysalis*** *The pale green chrysalis of the monarch butterfly becomes transparent when the pupa is ready to emerge*

## BUTTERFLY MIGRATION

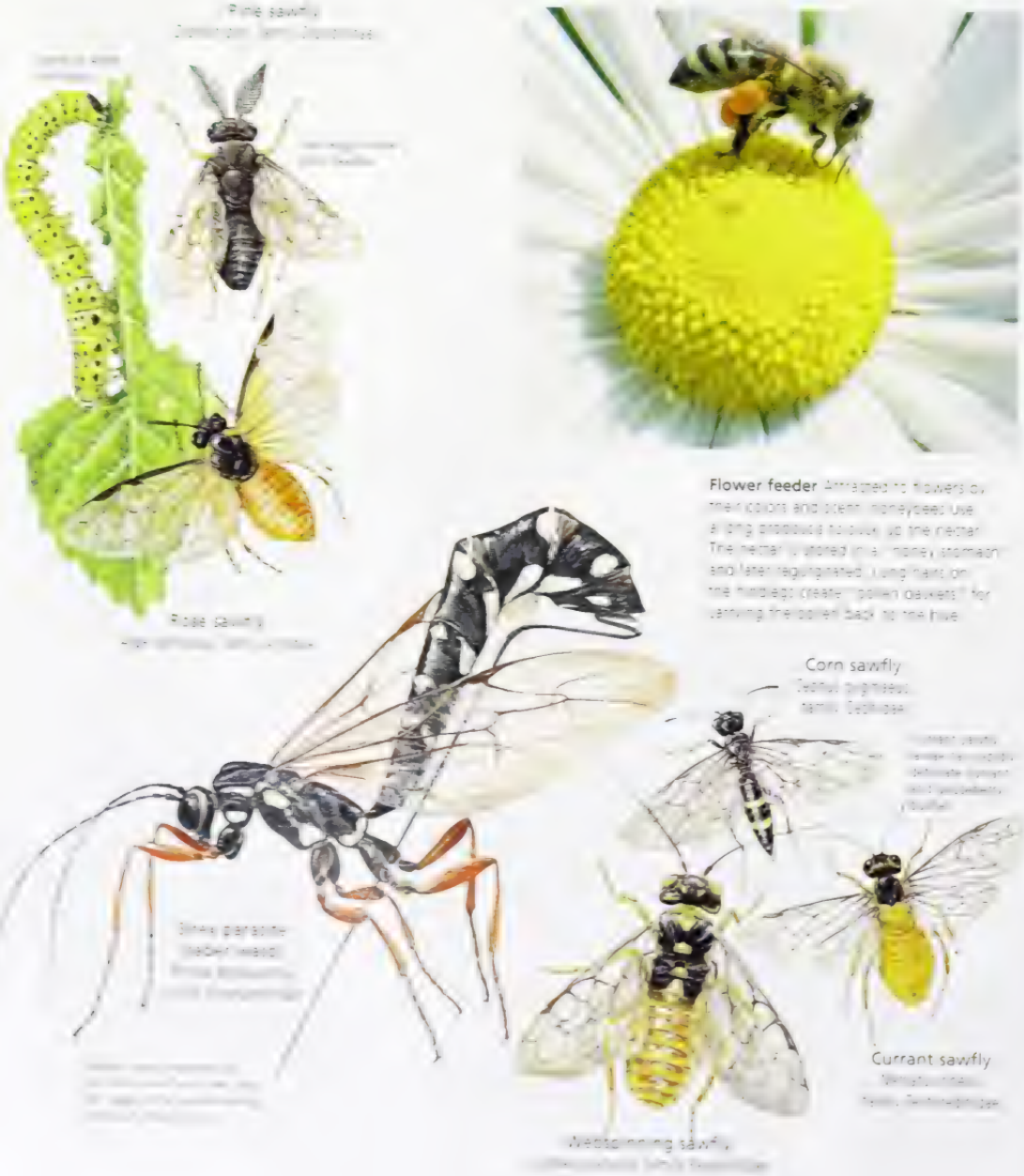
A monarch butterfly (*Danaus plexippus*) may travel more than 1,800 miles (2,900 km) in the 9 months of its life. Every autumn, millions of monarchs migrate south to their wintering sites in California and Mexico. Here they shelter in great clusters on trees. In autumn, they begin the [illegible] journey, during which they lay eggs and die. The new generation [illegible] the trip to the [illegible] breeding grounds.

# BEES, WASPS, ANTS, AND SAWFLIES

PHYLUM ARTHROPODA
SUBPHYLUM HEXAPODA
CLASS INSECTA
ORDER HYMENOPTERA
FAMILIES 91
SPECIES 116,000

The order Hymenoptera is named after the Greek words for "membrane wing," and most of its species have two pairs of transparent wings. Although many bees, wasps, and sawflies are solitary creatures, some species of bees and all species of ants live in highly structured societies, whose thousands or millions of members belong to different castes and perform specific tasks. Many of the world's most beneficial insects are hymenopterids. Bees and some wasps are the chief pollinators of both crops and wild plants, while many parasitic wasps play a crucial role in controlling the populations of other insects. Honeybees have been domesticated for their honey and wax.

**Bite and sting** Despite their formidable jaws, adult bull ants mainly eat nectar and plant juices, but they do capture insect prey to feed their young. They use an abdominal stinger to subdue prey and deter predators.



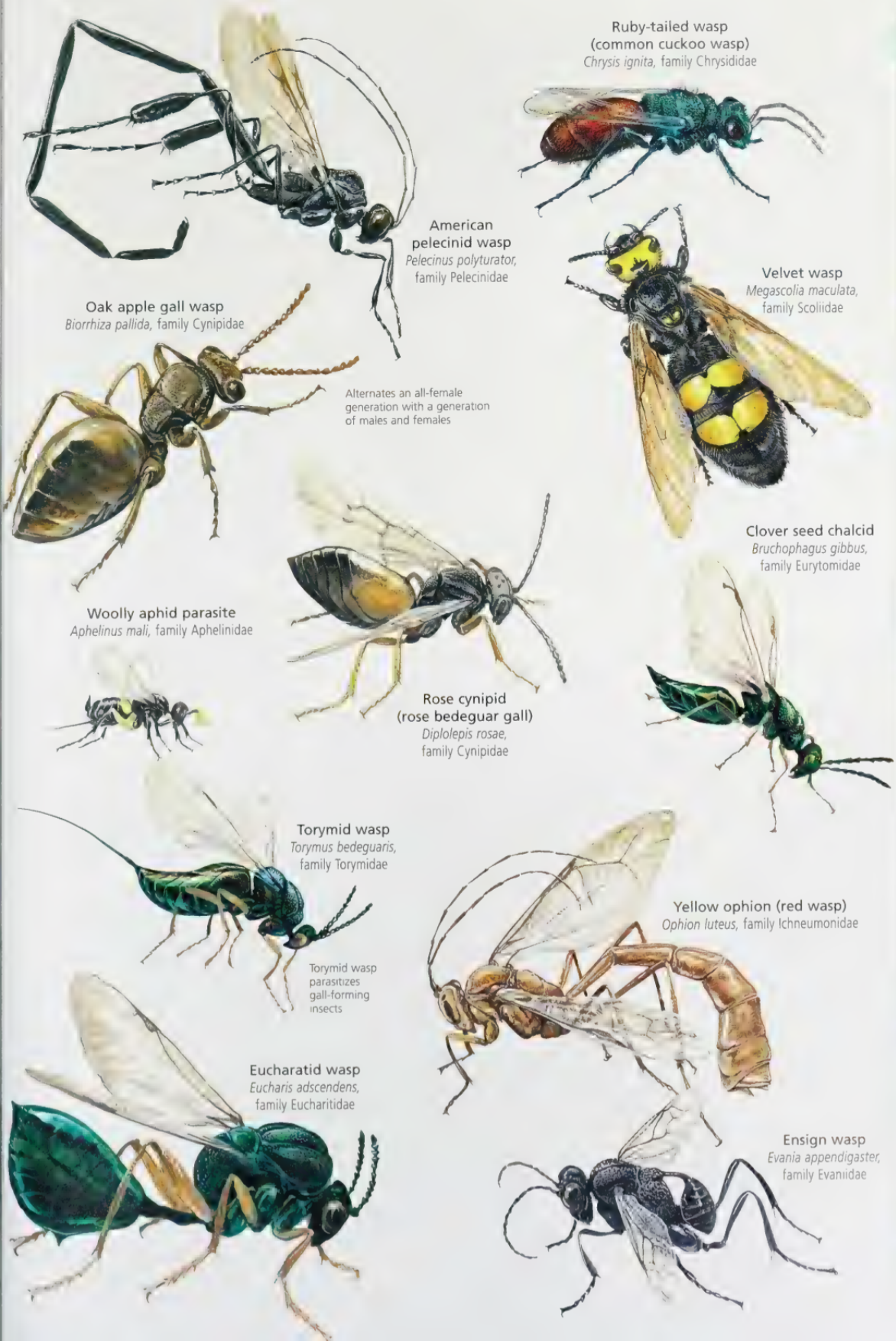

**Flower feeder** Attracted to flowers by their colors and scent, honeybees use a long proboscis to suck up the nectar. The nectar is stored in a "honey stomach" and later regurgitated. Long hairs on the hindlegs create "pollen baskets" for carrying the pollen back to the hive.

## ANATOMY AND LIFE-CYCLE

Generally small to medium-sized, hymenopterids include the parasitic *Megaphragma caribea*, which, at just [illegible] inch (0.17 mm) long, is one of the smallest insects. Hymenopterids' hindwings are attached to the larger forewings by tiny hooks so that they beat together. The more primitive sawflies and their kin lack the slim waist that separates the thorax and abdomen of bees, wasps, and ants.

Hymenopterids have mouthparts designed for biting or for biting and sucking. Sawflies, gall wasps, and some ants and bees are herbivorous, while most other species in the order are predatory or parasitic. In many species, the female's ovipositor (egg-laying organ) has become modified—sawflies use it for sawing into plant stems, where they lay their eggs; while bees, wasps, and ants often use it for piercing or stinging predators or prey.

Female hymenopterids may lay their eggs in soil, in plants, in nests or hives, or in living insect hosts. In many species, the female determines whether the eggs are fertilized, with unfertilized eggs producing male larvae, and fertilized eggs producing females. In solitary species, the larvae hatch near a food source and develop independently, but in social species they rely on constant care from the adults. Development is by complete metamorphosis, and larvae usually pupate in a cocoon.




## FACT FILE

**Family Chrysididae** Known as cuckoo wasps, ruby-tailed wasps, or jewel wasps, the species in this family lay their eggs in the nests of bees, wasps, or other insects. The cuckoo wasp larvae then feed on the nest's larvae or the food that has been provided for them. To resist the stings of the host insects, adult cuckoo wasps have a tough exoskeleton as well as a flexible body that can roll up into a ball.

Species 3,000

Worldwide; near flowers & insect hosts

***Peer parasites*** *Most cuckoo wasps lay their eggs in the nests of other wasps and bees, but some species parasitize sawflies, silk moths, or stick insects*

**Family Scoliidae** Adult scoliid wasps feed on flower nectar and pollen, but the larvae are parasites. The adult female will burrow into soil to find the grubs of scarab beetles. She then paralyzes each grub with a sting to the neck and lays an egg into it. When the wasp larva hatches, it will feed on the paralyzed grub, which dies once the larva pupates

Species 8,000

Worldwide; near scarab beetles

***Striped body*** *Scoliid wasps such as* Scolia procera *are relatively large and robust insects. Their hairy bodies often have bright markings*

**Family Cynipidae** This family contains the gall wasps, most of which are inconspicuous insects less than ¼ inch (5 mm) long. Females lay their eggs on oaks and other trees, where the larvae hatch and secrete saliva that forces the plant to form a protective gall around them. The larvae feed on the gall until they emerge through small holes as adults. Each cynipid species creates a characteristic gall

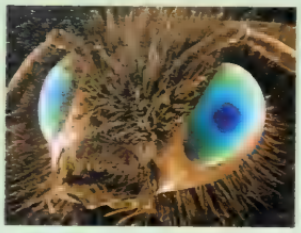
Species 1,400

Mainly Northern Hemisphere; on trees

***Rose galls*** *The larvae of the [illegible] develop from unfertilized eggs [illegible] bushes. About 50 larvae share [illegible] red filaments that make [illegible]*

# HIVE OF ACTIVITY

The social life of the honeybee (genus *Apis*) is among the most complex in the animal world. A queen bee can lay up to 1,500 eggs a day. Fertilized eggs develop into workers or queens, and unfertilized eggs become drones. The workers feed the hatched larvae before they are capped inside cells to pupate. When a hive reaches its optimum size, the old queen flies off to found a new colony, followed by thousands of workers. The first new queen to emerge will rule the old nest.

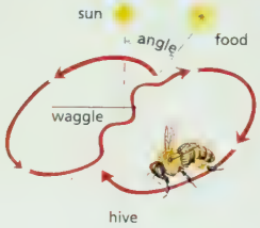


**Close view** This electron micrograph shows a honeybee's large compound eyes, each made up of more than 4,000 lenses. Two sensitive antennae emerge between the eyes.

**Honeybee swarm** A swarm of bees gathers when an old queen, along with up to 70,000 workers, leaves an established hive to establish a new colony. The swarm waits while scouts find a good location for the nest.

**Inside a beehive** All the drones and workers in a hive (below) are the offspring of the queen, whose only task is to lay eggs. Drones are male bees, and their only job is to mate with new queens. Worker bees gather food, maintain the hive, and feed the queen and her young. Glands in their head produce royal jelly for the larvae. Workers also make honey by regurgitating nectar and spreading it in cells to dehydrate, then capping it with wax.

**Bee young** Worker bees bring food to the larvae as they mature inside water-resistant waxen cells. These larvae (above) are transforming into pupae, and will emerge as adults.




**Dance of the bees** A worker bee uses a figure-eight dance to convey information about a new food source. The rate of tail-waggling indicates the distance to the food source, while the direction is signaled by the angle of the dance to the sun.

**Anthophorid digger bee**
*Anthophora parietina*, family Anthophoridae

Halictidae is a large family of solitary bees that nest in subterranean tunnels

**Halictid bee**
*Halictus quadricinctus*, family Halictidae

Mining bees often share ground nests, but do not work together or share a queen

**Mining bee**
*Colletes cunicularius*, family Colletidae

**Carpenter bee**
*Xylocopa violacea*, family Anthophoridae

**Sand digger wasp**
*Ammophila sabulosa*, family Sphecidae

Drags paralyzed prey back to sand burrow

Mason bees build their nests in empty snail shells

**Mason bee**
*Osmia bicolor*, family Megachilidae

**Red-tailed bumblebee**
*Bombus lapidarius*, family Apidae

Bumblebee colonies die out each autumn, with only young mated females overwintering to start new colonies in spring

Paper wasp builds nest by rolling balls of wood particles and saliva into paper-thin walls

**Common wasp**
*Vespula vulgaris*, family Vespidae

**Potter wasp**
*Eumenes pomiformis*, family Eumenidae

**Paper wasp**
*Polistes gallicus*, family Vespidae

## FACT FILE

**Family Sphecidae** This family includes species known as digger wasps, sand wasps, mud-dauber wasps, and thread-waisted wasps. A female sphecid wasp paralyzes arthropod prey with her sting and deposits it in her nest, where her larvae later feed on its body. Most species have their nests underground in burrows, but some use plant stems or rotten wood, and mud daubers build rows of cells from pellets of mud.

Species 8,000

Worldwide, often in sandy soil

***Solitary hunter*** The female bee-wolf (Philanthus triangulum) whisks paralyzed honeybees back to her sandy burrow.

**Family Apidae** The honeybees, bumblebees, and stingless bees in this family live in communal nests centered on a queen. Worker bees forage for nectar and pollen, which they bring back to the nest to feed the queen and her larvae. While honeybees often attach their hives to trees, bumblebees usually create their nests in the soil.

Species 1,000

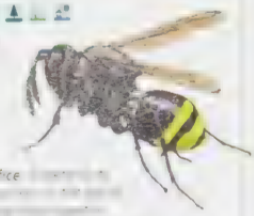
Worldwide, near flowers

***Fierce bee***
When provoked, a colony of Southeast Asian giant honeybees (Apis dorsata) is capable of stinging a person to death.

**Family Vespidae** This family contains all the social wasps, as well as some solitary ones. Hornets, yellowjackets, and paper wasps all use chewed wood and saliva to build their papery nests. In most species, the colony dies out in late autumn, leaving only a few mated queens to overwinter and establish new colonies in spring.

Species 4,000

Worldwide

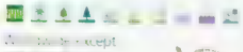


***Self-sacrifice*** [illegible]

## FACT FILE

**Family Formicidae** All ants belong to this family, which, according to some estimates, makes up 10 percent of the world's animal biomass. They are eusocial insects, which could help to account for their extraordinary success. Nests may contain from a mere 50 to many thousands of individuals. They are usually made of sand, twigs, or gravel and can be built underground or aboveground. Some species will sting to defend themselves, while others eject formic acid. Many ants are omnivorous, though some have specialized to feed on particular plants or on the honeydew produced by aphids.

Species 10,000



Absent except dry polar regions

***Tiny burglar***
*The minute thief ant Solenopsis fugax sneaks into the nests of other ant species to steal food.*

***Snapping mandibles***
The tropical ant Odontomachus haematodus (bauri) flicks its jaws at predators with great force, sometimes with its own venom.

## ANT SOCIETY

Unlike ant societies vary in complexity, but all contain three basic castes—queen, worker, and male. A new colony forms when winged females and males disperse from a nest and mate. The queen dies, while the females lose their wings and start to lay eggs as queens.

***Queen*** Almost monomorphic, the queen is larger than a worker, having a longer thorax and abdomen.

***Male*** Unusual among insects, male ants are produced from unfertilized eggs. Their only function is to mate with a queen.

***Soldier*** Found among species with polymorphic workers, soldiers have large heads and are adapted for defending the colony from enemies.

***Worker*** Sterile female ants, workers make up the majority of the colony. They perform all the work, including foraging, building the nest, and looking after the young.

*Myrmica lemnodis* family Formicidae

**Honey ant**
*Myrmecocystus hortideorum*, family Formicidae

Honey ants called repletes store food in their swollen abdomen and hang from the ceiling of the colony's nest

*Myrmica lemnodis* feeds on honeydew produced by aphids in return for protecting them from parasites

*Formica rufa* worker

**Red wood ant**
*Formica rufa*, family Formicidae

*Formica rufa* queen

*Formica rufa* male

Leafcutter workers carry leaf fragments up to three times their own weight

**Pharaoh ant**
*Monomorium pharaonis*, family Formicidae

**Carpenter ant**
*Camponotus herculeanus*, family Formicidae

**Leafcutter ant**
*Atta sexdens*, family Formicidae

**Slave-making ant**
*Polyergus rufescens*, family Formicidae

Slave-making ant raids nests of closely related species to steal pupae, which then emerge in its own nest and become its workers

**Giant hunting ant**
*Dinoponera grandis*, family Formicidae

**Bull ant**
*Myrmecia forficata*, family Formicidae

**Weaver ant**
*Oecophylla smaragdina*, family Formicidae

# OTHER INSECTS

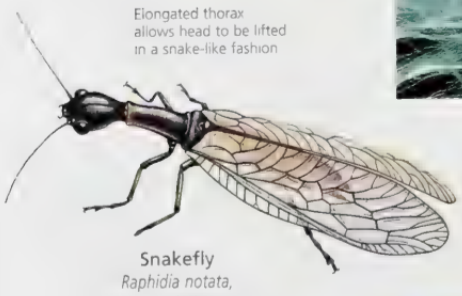
**PHYLUM** Arthropoda
**SUBPHYLUM** Hexapoda
**CLASSES** Insecta
**ORDERS** 19*
**FAMILIES** 218*
**SPECIES** > 3,000*

* *Totals refer only to the 19 orders that make up "Other insects."*

The remaining 19 orders of Insecta are a diverse assortment. They include primitive, wingless forms such as silverfish and bristletails; mammal parasites such as fleas and lice; insect parasites such as strepsipterans (order Strepsiptera); crop pests such as thrips; and insects that spend most of their lives in water, such as mayflies, caddisflies, dobsonflies, and stoneflies. Stick insects and leaf insects are plant-feeders; angel insects (order Zorotypidae), snakeflies, antlions, lacewings, and hanging flies prey on other invertebrates; rock crawlers (order Grylloblattodea), webspinners, earwigs, and scorpionflies recycle detritus; and some booklice species will feed on paper or stored cereals.

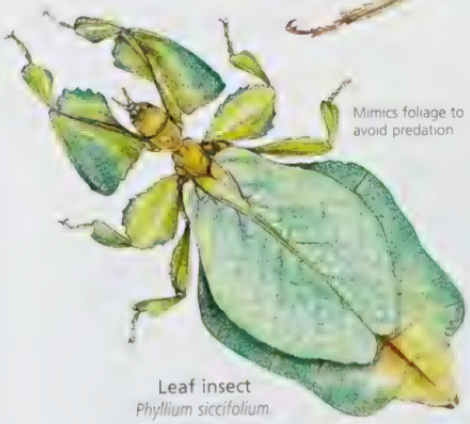
**Earwigs** The order Dermaptera contains the earwigs, small flattened insects that feed on detritus. The large "forceps" extending from the abdomen are used in defense and courtship. Females guard their eggs and newly hatched larvae

**Webspinners** The only insects other than danceflies with silk-producing glands in the legs, webspinners (order Embioptera) use their silk to create a shared network of nests and tunnels. They develop by incomplete metamorphosis, with nymphs resembling their parents




Snakefly
*Raphidia notata*, order Raphidioptera

Spiny devil walking stick
*Eurycantha horrida*, order Phasmatodea




Leaf insect
*Phyllium siccifolium*, order Phasmatodea

Silverfish
*Lepisma saccharina*, order Thysanura

Bristletail
*Machilis helleri*, order Archaeognatha

## FACT FILE

**Order Thysanura** This order contains the silverfish, flightless insects that may closely resemble the earliest insects. They have long antennae on their head, and three "tails" extending from the abdomen. Silverfish hatch from eggs laid in crevices near food sources

**Species** 370

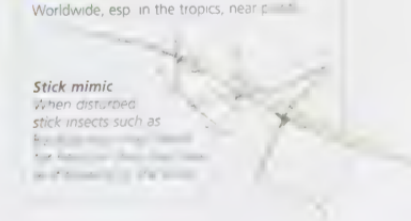
Worldwide; in trees, caves & buildings

***House guest*** *This silverfish (Lepismodes iniquilinus) is often found in houses, where it feeds on paper, glue in book bindings, starched clothing, and dry foods*

**Order Phasmatodea** The supreme mimics in this order are known as stick insects and leaf insects. They feed on foliage. Most species are wingless, and, when wings are present, they usually are fully developed and functional only in the males. Many females can produce offspring from unfertilized eggs

**Species** [illegible]

Worldwide, esp in the tropics, near [illegible]



***Stick mimic*** *When disturbed stick insects such as* [illegible]

## FACT FILE

**Order Ephemeroptera** The mayflies in this order live very short lives as adults, often lasting only a day. The males form great swarms from which females select mates. Eggs are deposited in or near water, and the nymphs are aquatic. Nymphs leave the water to molt into winged forms, which soon molt again into the adults. Mayflies are the only insects to molt once they have wings.

Species 2,500

Worldwide; in fresh or brackish water

***Flying romance*** *Mayflies mate in flight, with the male using his long forelegs to grasp the female*

**Order Megaloptera** The dobsonflies and alderflies in this order spend most of their lives as predatory aquatic larvae. They leave the water to pupate, emerging as winged adults that usually do not feed and only live long enough to breed. Eggs are usually laid on rocks or plants beside ponds or streams, and the larvae crawl or fall into the water.

Species 300

Worldwide; in fresh water

***Toebiter*** *The larva of the dobsonfly* Archichauliodes *is known as the "toebiter." It breathes through the leg-like gills along its abdomen.*

**Order Phthiraptera** The parasitic lice in this order are tiny wingless insects that evolved from winged ancestors. They feed on birds and mammals and cannot survive long away from their host. Lice can travel to a new host only when two members of the host species come into contact, which restricts most lice to particular host species. Some lice have sucking mouthparts, while others have chewing mouthparts

Species 5,500

Worldwide, on bird or mammal hosts

***Louse bites dog*** *The dog-biting louse (Trichodectes canis) uses its chewing mouthparts to feed on the hair, skin, and blood of domestic dogs and other canids. Gripping claws on its legs make it difficult to dislodge.*

**Mayfly**
*Ephemera vulgata*, order Ephemeroptera

Mayflies are the only insects to hold their wings straight up

Nymph of *Ephemera vulgata* burrows in sandy riverbed and breathes through abdominal gills

**Alderfly**
*Sialis lutaria*, order Megaloptera

Less than 1/12 inch (2 mm) long, grain thrips infest small grains such as wheat and oats

**Grain thrip**
*Limothrips cerealium*, order Thysanoptera

*Ectopsocus briggsi*, order Psocoptera

Order Psocoptera contains book lice and bark lice

Book lice feed on paste and bindings of old books

**Book louse**
*Liposcelis divinatorius*, order Psocoptera

**Mantispid fly**
*Mantispa pagana*, order Neuroptera

**Eastern dobsonfly**
*Corydalis cornutus*, order Megaloptera

Male dobsonfly uses very long mandibles to grasp female during mating

**Pubic louse**
*Phthirius pubis*, order Phthiraptera

Pubic lice are parasites of humans and gorillas

**Human flea**
*Pulex irritans*, order Siphonaptera

Human fleas leap onto humans, pigs, goats, and other mammals using their large hindlegs

**Head louse**
*Pediculus capitis*, order Phthiraptera

## FACT FILE

**Order Neuroptera** The members of this order all have complex branching veins on their wings. Most are predators as both larvae and adults. Lacewing larvae are welcome in gardens because they devour aphids, mites, and scale insects. Antlion larvae live in sand and feed mainly on ants. Owlfly larvae live in leaf litter near stones, and prey on invertebrates. Spongefly larvae live in fresh water and eat only sponges

Species 4,000

Worldwide; often near vegetation

***Pit trap*** *Antlion larvae, known as doodlebugs in North America, dig pits in loose sand to trap ants and other prey.*

**Order Mecoptera** This order includes scorpionflies, named after the large tail the male uses to hold onto the female during mating, and hanging flies, which hang from leaves to hunt and mate. Males often offer their mates a nuptial gift of a prey item or a pellet of saliva that the female eats during copulation. Most species feed on detritus, insects, and plants.

Species 500

Worldwide; near damp vegetation

***Stingless scorpion***
*Like other males in its genus, the male common scorpionfly (Panorpa communis) is harmless but has an enlarged "tail" that resembles the stinger of a scorpion.*

**Order Plecoptera** The nymphs of the stoneflies in this order can indicate the environmental health of streams. They are entirely aquatic and can survive only in cool, clean, flowing water with high concentrations of oxygen. After going through up to 30 molts, nymphs crawl from the water and emerge as adults, which are usually winged

Species 3,000

Worldwide except Australia; near running water

***Feeding strategies***
*While adult stoneflies of the genus Perla [illegible] nymphs [illegible] er larvae*

# INSECT ALLIES

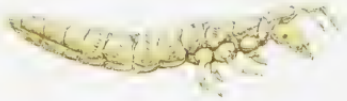
PHYLUM Arthropoda
SUBYPHYLUM Hexapoda
CLASSES 3
ORDERS 5
FAMILIES 31
SPECIES 8,300

Hexapods are arthropods with six legs and a body divided into three parts—head, thorax, and abdomen. The vast majority of hexapods are insects, but there are also three classes of non-insect hexapods—the springtails (class Collembola), proturans (Protura), and diplurans (Diplura). Found in soil and leaf litter, these tiny creatures range from 1/50 inch to 1¼ inches (0.5 mm to 3 cm) in length. They are distinguished from insects by their mouthparts, which are fully tucked into the head. As in the most primitive of insects, the silverfish and the bristletails, these tiny soil-dwellers evolved from a wingless ancestor and they continue to molt throughout their life.

**Ready to leap** Springtails are ubiquitous, occurring in freshwater, coastal marine, and most terrestrial habitats, including deserts and polar zones. They feed mainly on microorganisms. Surface-dwellers tend to be covered in hairs (above) or scales

*Entomobrya superba*
class Collembola

Long legs often found on surface-dwelling springtails



*Eosentomon ribagai,*
class Protura

Adapted to cold and often found in wet places, soil, and snow

*Isotoma viridis,*
class Collembola

*Hypogastrura sp.*
class Diplura

Giant springtail
Collembola

Giant springtail can reach ½ inch (9 mm) in length and has lost the ability to jump great distances, but deters the attacks of tiger beetles by releasing chemicals

*Campodea fragilis,*
class Diplura

Cerci have developed into pincers

A dipluran can regrow a lost leg, antenna, or cerci over several molts

*Catajapyx aquilonaris,*
class Diplura

Proturans hold their forelegs out in front of the body

## PRIMITIVE HEXAPODS

The springtails that make up the class Collembola are named after a forked organ on the abdomen that can propel them up to 100 times their own body length—a quick way to escape danger. They are among the most abundant animals, with populations of 300 million individuals per acre (750 million per ha) in some grassland habitats.

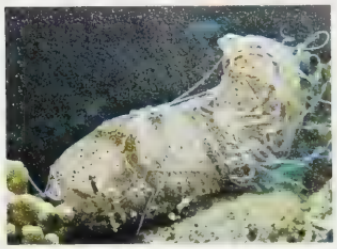
With a length of less than 1/12 inch (2 mm), proturans are rarely seen and were not even discovered until 1907. They live in soil and leaf litter, where they feed on fungi and decaying matter. They are the most primitive of all hexapods and lack eyes and antennae. Instead, the forelegs perform a sensory function and are held out in front of the animal rather than being used for walking. With each molt, proturans gain another segment of abdomen.

Diplurans lack eyes but feel their way around in soil or leaf litter with their long antennae and two tail-like structures known as cerci. In some carnivorous species, the cerci have become powerful pincers that can capture other soil-dwellers. Other species are herbivorous and feed on soil fungi and detritus. Diplurans are able to regenerate some of their body parts.

# ECHINODERMS

**PHYLUM** Echinodermata
**CLASSES** 5
**ORDERS** 36
**FAMILIES** 145
**SPECIES** 6,000

The sea stars, sea urchins, brittle stars, feather stars, and sea cucumbers that belong to the phylum Echinodermata display diverse body forms, but share some defining characteristics. Adults usually have pentamerous symmetry, with the body arranged into a five-part radial pattern around a central axis. Most internal organs are also arranged in this pattern. An internal skeleton of calcareous plates provides protection and support. The plates often bear spines or small lumps—the name echinoderm means "spiny skin." The body cavity includes a water-vascular system, a network of water vessels that controls the tube feet used for locomotion, feeding, respiration, and sensory functions.



**Sticky defense** In sea cucumbers, the five-part symmetry is internal and the skeleton is reduced. This leopard sea cucumber (*Bohadschia argus*) has ejected a mass of sticky white threads, known as cuvierian tubules, to confuse or entangle a predator

**Stalked young** All members of the class Crinoidea are initially attached to the substrate by a slender stalk, but feather stars such as this *Comanthus* sp. then become free-living. The branched arms hold tube feet that catch plankton from the water and transfer it to the mouth.

## SPINY BOTTOM-DWELLERS

All echinoderms are marine and most are mobile bottom-dwellers, although sea lilies are fixed to the seafloor by a long stalk, and a few sea cucumbers float in the open ocean. Echinoderms are found throughout the world at all depths. Sea urchins and sea stars are very commonly seen along the seashore.

The phylum Echinodermata is divided into five classes. Members of the class Crinoidea include the sessile sea lilies as well as the mobile feather stars. They are filter-feeders and, unlike other echinoderms, have their mouth facing away from the substrate. The other echinoderm classes include predators, grazers of algae, and deposit-feeders. The sea stars of class Asteroidea and brittle stars of class Ophiuroidea have arms radiating from their body. Their skeletal plates are held together by muscles, which allows flexibility. In the class Echinoidea, sea urchins and sand dollars have a rigid skeleton of fused plates that supports a globular or flattened form, usually featuring prominent spines. Sea cucumbers (class Holothuroidea) are generally soft-bodied, with their skeletons reduced to minute spicules.

Although a few echinoderms can reproduce asexually, most have separate sexes that release eggs and sperm into the water for fertilization. The larvae are often free-swimming and metamorphose into bottom-dwelling adults. In some species, the larval stage is omitted, and the newly hatched young resemble small adults.

**Spiky gathering** Many echinoderms, such as these sea urchins, gather in large groups, influenced by the availability of food. The strategy may also provide some protection from predators and enhance reproduction

## FACT FILE

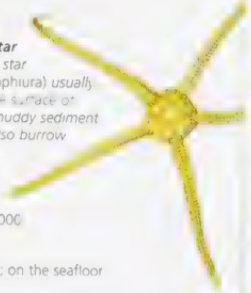
**Class Asteroidea** Also known as starfish, the sea stars in this class move and feed using the suckered tube feet along their arms. Most are predators that evert their stomach over sessile or slow-moving prey to begin digesting it. Some use their tube feet to prise open the shells of bivalves such as clams. Sea stars are usually vibrant colors such as red, orange, or purple and may have a smooth, spiny, or ridged surface

Species 1,500

Worldwide, on the seafloor

***Many arms*** *The common sun star (Crossaster papposus) can have as many as 40 arms and grow to about 1 foot (30 cm) in diameter*

**Class Ophiuroidea** In contrast to sea stars, in which the arms grade into the central disk, the brittle stars and basket stars of Ophiuroidea have sharply demarcated arms. Rather than using their tube feet to crawl, they move by using any two of their flexible, jointed arms in a breast-stroke action. The class includes predators, scavengers, and filter-feeders



***Surface star*** *The brittle star (Ophiura ophiura) usually lives on the surface of sandy or muddy sediment but may also burrow shallowly*

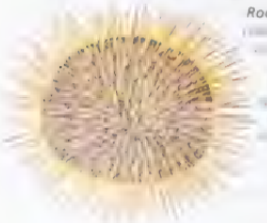
Species 2,000

Worldwide, on the seafloor

**Class Echinoidea** The sea urchins in this class have a spherical body protected by a skeletal case called a test, and long, movable spines. Sand dollars are flattened and covered in smaller spines. Many echinoids have a system of plates, muscles, and teeth known as the Aristotle's lantern, with which they scrape algae from rocks

Species 950

Worldwide, on the seafloor



***Rock burrower*** *A [illegible]*

**Spiny starfish**
*Marthasterias glacialis*, class Asteroidea

The spiny starfish can reach a diameter of 28 inches (70 cm)

**Sand dollar (sea biscuit)**
*Clypeaster humilis*, class Echinoidea

**Reef sea urchin**
*Diadema setosum*, class Echinoidea

Sea urchins move slowly using their tube feet and spines

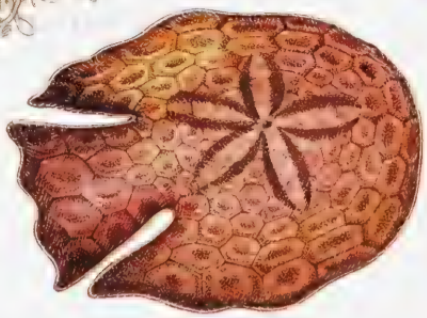
**Black brittle star**
*Ophiocomina nigra*, class Ophiuroidea

The arms of brittle stars are easily broken off, hence the common name

**Gorgon's head**
*Astrospartus mediterraneus*, class Crinoidea

**Goose-foot starfish**
*Anseropoda placenta*, class Asteroidea

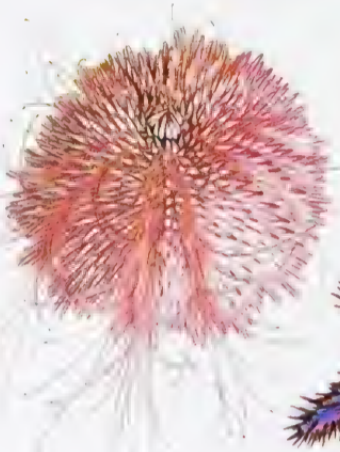
**Heart urchin (sea potato)**
*Echinocardium cordatum*, class Echinoidea



**Sea pancake**
*Echinodiscus auritus*, class Echinoidea

**Cushion star**
*Culcita novaeguineae*, class Asteroidea

**Edible sea urchin**
*Echinus esculentus*, class Echinoidea



**Crown-of-thorns starfish**
*Acanthaster planci*, class Asteroidea

An increase in the numbers of this coral predator has devastated large areas of the Great Barrier Reef

**African red knob sea star**
*Protoreaster linckii*, class Asteroidea

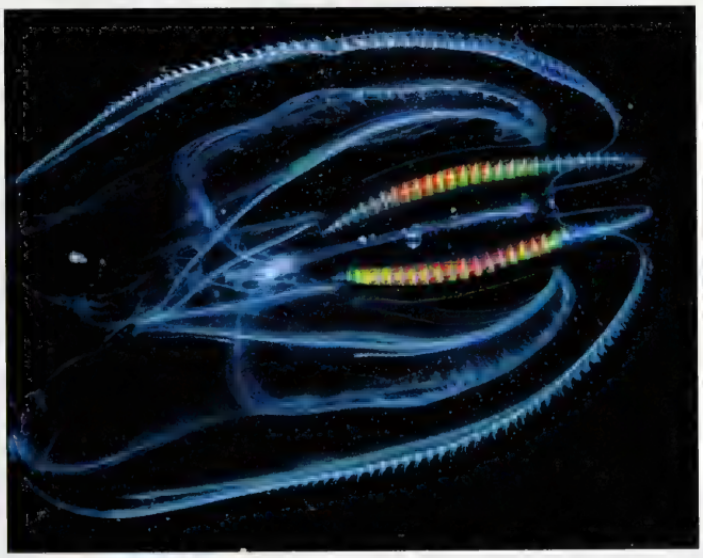
# OTHER INVERTEBRATES

| MINOR INVERTEBRATE PHYLA |
|---|
| PHYLA 25 |
| CLASSES > 40 |
| ORDERS > 60 |
| SPECIES > 12,000 |

The preceding pages have covered eight major invertebrate phyla, as well as two subphyla of invertebrate chordates. There are, however, another 25 phyla of invertebrates, many of which are profiled in this chapter. Although the phylum Bryozoa contains 5,000 species, most of these minor groups are small—Phoronida (horseshoe worms), for example, contains a mere 20 species. The members of these phyla also tend to be physically small and are often microscopic. Most are marine, although many are found in fresh water and some occur on land. Often overlooked, the minor invertebrate phyla all display fascinating solutions to the challenges presented by their environment.

**Ribbon worms** Roughly 1,000 species of long ribbon worms make up the phylum Nemertea. The majority are marine, but some live in fresh water or moist soil. They trap or stab their invertebrate prey using a unique projectile proboscis.

**Invading comb jelly** Native to America's Atlantic coast, the sea walnut (*Mnemiopsis leidyi*) was accidentally introduced into the Black Sea in the early 1980s. Explosive population growth followed, and soon this predator of zooplankton and fish eggs and larvae had devastated the ecosystem and triggered fishery crashes.



**Extreme survivors** Water bears such as *Echiniscus testudo* (shown here magnified) are able to survive environmental stress by entering cryptobiosis, a death-like state. They can survive for years before reviving when conditions become favorable.

## FACT FILE

**Phylum Entoprocta** Attached by a stalk to the substrate, goblet worms use a ring of mucus-secreting tentacles to filter particles from the water. Many species form colonies by budding.

Species 150

Worldwide; mostly on the seafloor

**Phylum Tardigrada** Unknown until 1773, following the invention of the microscope, water bears crawl over ocean sediment, soil, or plants with a slow, bear-like gait. These minute creatures occur in almost all aquatic and moist terrestrial environments.

Species 600

Worldwide; aquatic & moist land habitats

**Phylum Ctenophora** The marine comb jellies that make up this phylum swim by beating the fused cilia (tiny hairs) arranged in eight comb rows along their body. They engulf their prey directly or capture it with a pair of sticky, retractable tentacles

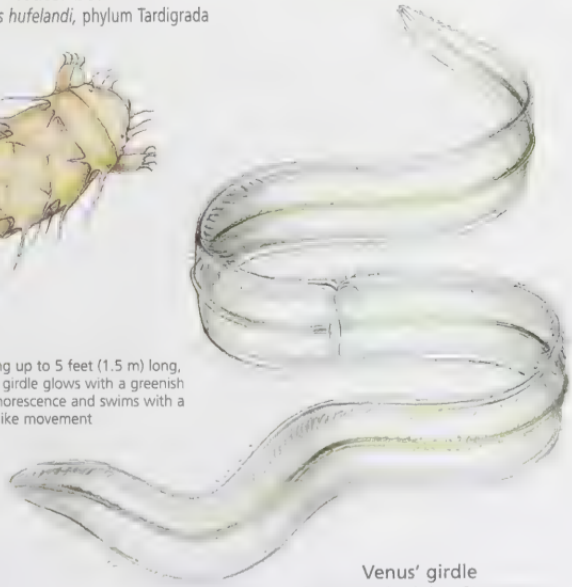
Species 100

Worldwide; mostly planktonic

Water bear
*Macrobiotus hufelandi*, phylum Tardigrada

This solitary species can move about on its suckered stalk

Goblet worm
*Loxosoma harmeri*, phylum Entoprocta



Growing up to 5 feet (1.5 m) long, Venus' girdle glows with a greenish phosphorescence and swims with a snake-like movement

Venus' girdle
*Cestus veneris*, phylum Ctenophora

Melon jellyfish
*Beroe cucumis*, phylum Ctenophora

Can engulf prey (such as other comb jellies) that are as large as itself

## FACT FILE

**Phylum Rotifera** Sometimes known as wheel animals, rotifers are microscopic aquatic creatures. A crown of cilia (hair-like structures) around the mouth beat rapidly to collect food and propel the rotifer, creating the impression of a whirling wheel. The trunk is often protected by a stiffened epidermis and sometimes bears defensive spines. Most rotifer species are found in fresh water, where they make up much of the zooplankton.

Species 1,800

Worldwide, in aquatic vegetation & moist terrestrial habitats

***Swimming rotifer*** *Many rotifer species, including* Brachionus plicatilis, *are free-swimming. Others use their cement-producing toes to attach to a surface*

**Phylum Hemichordata** Known as acorn worms or hemichordates, the members of this phylum have a three-part body made up of a proboscis at the head; a collar in the middle, which bears tentacles in some species; and a trunk containing the digestive and reproductive organs. They feed on small particles, either filtered from the water or consumed with sediment.

Species 90

Worldwide, on the seafloor

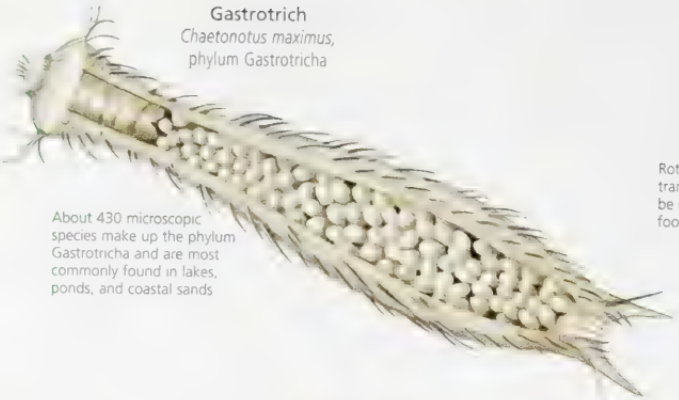
***Close relatives*** *Hemichordates, such as* Saccoglossus cambrensis, *are closely related to the chordates but lack a notochord*

**Phylum Chaetognatha** The arrow worms of this phylum are voracious predators. Their head has up to 14 large grasping spines for seizing prey such as copepods or small fishes. When the spines are not in use, a hood formed from the body wall covers the head to protect them. Most species are planktonic and many migrate from deeper waters to feed at the surface at night.

Species 90

Worldwide, in plankton & on the seafloor

***Torpedo worm*** *Like other arrow worms, [illegible] has a torpedo-shaped [illegible] trunk and ventral fins for [illegible] and a tail fin for thrust*



**Gastrotrich**
*Chaetonotus maximus*, phylum Gastrotricha

About 430 microscopic species make up the phylum Gastrotricha and are most commonly found in lakes, ponds, and coastal sands

Rotifers are generally transparent but can be colored by their food as it is digested

**Rotifer**
*Philodina roseola*, phylum Rotifera

**Arrow worm**
*Spadella cephaloptera*, phylum Chaetognatha

Often found in European tide pools

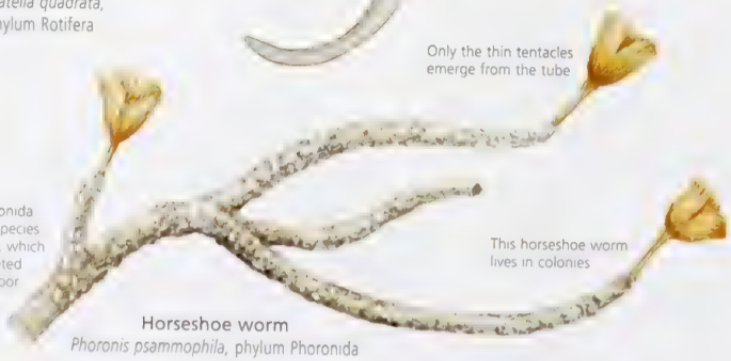
**Acorn worm**
*Balanoglossus clavigerus*, phylum Hemichordata

The largest acorn worms can be 8 feet (2.5 m) long

**Spiny-crown worm**
*Echinoderes* sp., phylum Kinorhyncha

The 150 species in the phylum Kinorhyncha are tiny burrowing marine worms with a segmented body

**Rotifer**
*Keratella quadrata*, phylum Rotifera

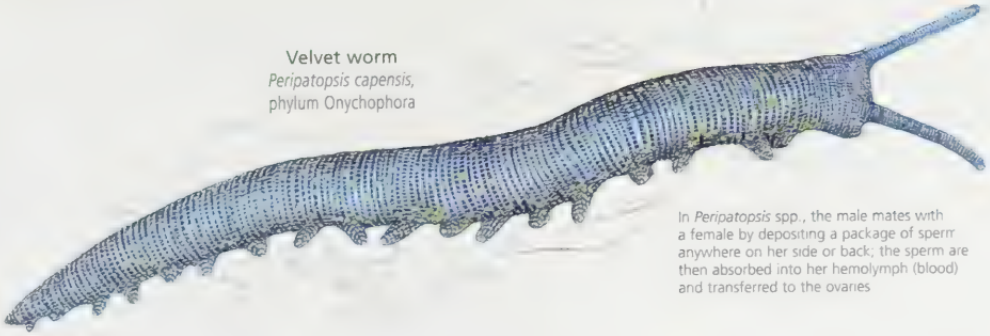


Only the thin tentacles emerge from the tube

The phylum Phoronida contains just 20 species of marine worms, which live in tubes secreted on or in the seafloor

This horseshoe worm lives in colonies

**Horseshoe worm**
*Phoronis psammophila*, phylum Phoronida



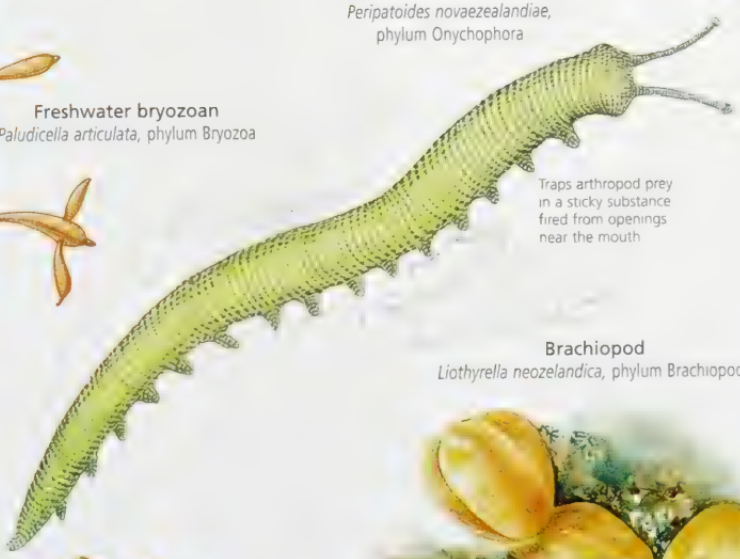
Velvet worm
*Peripatopsis capensis*, phylum Onychophora

In *Peripatopsis* spp., the male mates with a female by depositing a package of sperm anywhere on her side or back; the sperm are then absorbed into her hemolymph (blood) and transferred to the ovaries

Velvet worm
*Peripatus torquatus*, phylum Onychophora

Freshwater bryozoan
*Paludicella articulata*, phylum Bryozoa

New Zealand peripatus
*Peripatoides novaezealandiae*, phylum Onychophora



Traps arthropod prey in a sticky substance fired from openings near the mouth

Brachiopod
*Liothyrella neozelandica*, phylum Brachiopoda

Bryozoan
*Myriopora truncata*, phylum Bryozoa

Unlike most bryozoans, which are fixed, a colony of *Cristatella mucedo* can creep on its flattened underside

Freshwater bryozoan
*Cristatella mucedo*, phylum Bryozoa

## FACT FILE

**Phylum Onychopora** Since their thin non-waxy cuticle does little to prevent water loss, the velvet worms of this phylum are restricted to moist, [illegible] habitats. They are found in leaf litter and soil and under stones and rotting logs. To entangle insects and other prey, velvet worms squirt out sticky threads from slime glands near the mouth, a technique that can also be used in defense

Species 70

Tropical, S southern temperate zones.

***Like velvet*** [illegible] velvet worms, Peripatus [illegible] is covered in [illegible] that give it a velvet appearance. The [illegible] body can have 13 to 43 pairs of stumpy legs.

**Phylum Brachiopoda** With their bivalved shells, brachiopods look like clams or mussels, but are in fact much more closely related to bryozoans. Both brachiopods and bryozoans filter food particles from the water with a lophophore, a crown of hollow tentacles around the mouth

Species 350

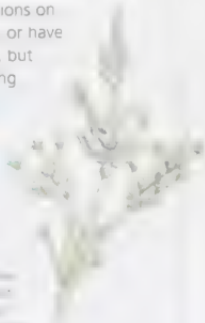
Worldwide, on the seafloor at all levels of the ocean.

***Burrowing stalk*** The [illegible] brachiopods [illegible] attach themselves to [illegible]

**Phylum Bryozoa** Sometimes called moss animals, bryozoans are tiny, aquatic, and colonial. Most secrete a protective covering around the body with an opening for the lophophore (feeding tentacles). Created by budding, the colonies usually grow as encrustations on rocks or seaweed, or have a branching form, but a few are free-living

Species 5[illegible]

Worldwide, on the bottom of aquatic habitats.



***Fixed in place*** [illegible]

# GLOSSARY

**abdomen** The part of the body containing the digestive system and the reproductive organs. In insects and spiders, the abdomen makes up the rear of the body.

**adaptation** A change in an animal's behavior or body that allows it to survive and breed in new conditions.

**adaptive radiation** A situation in which animals descended from a common ancestor evolve to exploit different ecological niches that are not being filled by other animals, as in the finches of the Galápagos Islands and the lemurs of Madagascar.

**algae** The simplest forms of plant life.

**altricial** Helpless at birth. Describes newly hatched chicks of some birds; cf precocial.

**amphibious** Able to live on land and in water. Amphibians (frogs, toads, salamanders, caecilians, and newts) are vertebrates that are similar to reptiles, but have moist skin and lay their eggs in water.

**amplexus** A breeding position of frogs and toads, in which the male holds the female with his front legs.

**anadromous** Living in the ocean but returning to fresh water to spawn, as in salmon; cf catadromous.

**anal fin** An unpaired fin on the lower surface of a fish's abdomen. It plays an important role in swimming.

**annulus** (pl. annuli) A marking resembling a ring, as in caecilians; or a growth ring, as on a scale of a fish, that is used in estimating age.

**antenna** (pl. antennae) A slender organ on an animal's head, used to sense smells and vibrations around it. Insects have two antennae.

**antlers** Bony, often branched growths from the head of deer and moose. In most cases, they are grown and shed each year. They are used as weapons and for display; cf horns.

**aquaculture** Cultivation of the resources of the sea or inland waters, as opposed to their exploitation.

**aquatic** Living all or most of the time in water; cf amphibious, terrestrial.

**arachnid** An arthropod with four pairs of walking legs; includes spiders, scorpions, ticks, and mites.

**arboreal** Living all or most of the time in trees.

**arthropod** An animal with jointed legs and a hard exoskeleton. Arthropods make up the largest group of animals on Earth and include insects, spiders, crustaceans, centipedes, and millipedes.

**avian** Of or about birds. Birds form the class Aves in the animal kingdom.

**baleen** The comb-like, fibrous plates found in some whales; often referred to as whalebone. The plates hang from the upper jaw and are used to sieve food from sea water.

**barb** A part of a bird's feather. Barbs emerge from the central shaft of a feather in a parallel arrangement, like the teeth on a comb.

**barbel** A slender, fleshy outgrowth on an animal's lips or near its mouth. It is equipped with sensory and chemical receptors and is used by such animals as bottom-dwelling fishes to find food.

**benthic** Relating to or occurring at the bottom of a body of water or the depths of the ocean; bottom dwelling (as in fishes).

**biodiversity** The total number of species of plants and animals in a particular location.

**birds of prey** Flesh-eating land birds that hunt and kill their prey. Hawks, eagles, kites, falcons, buzzards, and vultures are diurnal birds of prey; owls are nocturnal birds of prey.

**blubber** A thick layer of insulating fat in whales, seals, and other large marine mammals.

**bony fish** A fish with a bony skeleton. Other characteristics are a covering over the gills, and a swim bladder. Most bony fishes also have scales on their skin.

**book lungs** Lungs found in primitive insects and arachnids, consisting of "pages" of tissue through which blood and oxygen circulate.

**brachiation** A form of movement in which an animal (such as an ape) swings from hold to hold by its arms.

**brood parasite** An animal, often a bird, that tricks another species into raising its young, as in some cuckoos. A young brood parasite often kills all its nestmates so that they do not compete with it for food or care.

**browser** A plant-eating mammal that uses its hands or lips to pick leaves from trees and bushes (as in koalas and giraffes) or low-growing plants (as in the black rhino).

**camouflage** The colors and patterns of an animal that enable it to blend in with the background. Camouflage conceals the animal from predators and helps it to ambush prey.

**canine teeth** The teeth between the incisors and molars of mammals.

**carnassials** Special cheek teeth with sharp, scissor-like edges used by carnivores to tear up food.

**carnivore** An animal that eats mainly meat. Most carnivorous mammals are predators; others are both predators and scavengers. Most carnivores eat some plant material as well as meat.

**carrion** The rotting flesh and other remains of dead animals.

**cartilaginous fish** A fish with a skeleton made of cartilage, such as a shark, ray, or chimaera.

**catadromous** Living in fresh water but returning to the sea to spawn, as in freshwater eels; cf anadromous.

**caudal** Relating to an animal's tail. In fishes, the caudal fin is the tail fin.

**cephalic** Of, relating to, or situated on or near the head.

**cephalothorax** In arachnids and crustaceans, a region of the body that combines the head and thorax. It is covered by a hard body case.

**chelicera** (pl. chelicerae) A pincer-like, biting mouthpart, such as a fang, as in spiders, ticks, scorpions, and mites.

**chitin** A hard, plastic-like substance that gives an exoskeleton its strength.

**chrysalis** The form taken by a butterfly in the pupal stage of its metamorphosis, or the case in which it undergoes this stage.

**claspers** The modified inner edges of the pelvic fins of male sharks, rays, and chimaeras, used for the transferring of sperm to the female.

**cloaca** An internal chamber in fishes, amphibians, reptiles, birds, and monotremes, into which the contents of the reproductive ducts and the waste ducts empty before being passed from the body.

**clutch** The full and completed set of eggs laid by a female bird or reptile in a single nesting attempt.

**cocoon** In insects and spiders, a case made of silk used to protect themselves or their eggs. In amphibians, a protective case made of mud, mucus, or a similar material, in which the animal rests during estivation.

**cold-blooded** See ectothermic.

**complete metamorphosis** A form of development in which a young insect changes shape from an egg to a larva, to a pupa, to an adult. Insects such as beetles and butterflies develop by complete metamorphosis.

**compound eye** An eye that is made up from many smaller eyes, each with its own lens; found in most insects, but not in spiders.

**conspecific** Of the same species.

**convergent evolution** The situation in which totally unrelated groups develop similar structures to cope with similar evolutionary pressures.

**coral reef** A structure made from the skeletons of coral animals, or polyps, found in warm waters.

**crest** In lizards, a line of large, scaly spines on the neck and back. In birds, a line of feathers on the top of the head. Lizards and many birds can raise or lower the crest as a means of communication with others.

**crop** A thin-walled, saclike pocket of the gullet, used by birds to store food before digestion or to feed chicks by regurgitation.

**crocodilians** Crocodiles, caimans, alligators, and gavials. Members of the order Crocodilia.

**crustacean** A mostly aquatic animal, such as a lobster, crab, or prawn, that has a hard external skeleton.

**deforestation** The cutting down of forest trees for timber, or to clear land for farming or building.

**dewlap** In a lizard, a flap of skin, sometimes brightly colored, on the throat. A dewlap usually lies close to the neck and can be extended to communicate with other lizards.

**dimorphic** Having two distinct forms within a species. Sexual dimorphism is the situation in which the male and female of a species differ in size and/or appearance.

**dinosaurs** A group of reptiles that dominated Earth from the Triassic to the Cretaceous Period (245–65 million years ago). The largest land animals that ever lived, dinosaurs are more closely related to today's birds and crocodilians than they are to other living reptiles.

**dioecious** Born either male or female and remaining that way through life; cf hermaphroditic.

**display** Behavior used by an animal to communicate with its own species, or with other animals. Displays can include postures, actions, or showing brightly colored parts of the body, and may signal threat, defense, or readiness to mate.

**diurnal** Active during the day. Most reptiles are diurnal because they rely on the Sun's heat to provide energy for hunting and other activities.

**divergent evolution** The situation in which two or more similar species become more and more dissimilar due to environmental adaptations.

**DNA** A molecule, found in chromosomes of a cell nucleus, that contains genes. DNA stands for deoxyribonucleic acid.

**domestication** The process of taming and breeding an animal for human use. Domesticated animals include pets, as well as animals used for sport, food, or work, such as sheep, horses, and dairy cattle.

**dorsal fin** The large fin on the back of some fishes and aquatic mammals, which helps the animal to keep its balance as it moves through the water. Some fishes have two or three dorsal fins.

**dragline** A strand of silk that spiders leave behind them as they move about.

**drone** A male honeybee. Drones mate with young queens, but unlike worker bees, they do not help in collecting food or maintaining the hive.

**echolocation** A system of navigation that relies on sound rather than sight or touch. Dolphins, porpoises, many bats, and some birds use echolocation to tell them where they are, where their prey is, and if anything is in their way.

**ecosystem** A community of plants and animals and the environment to which they are adapted.

**ectothermic** Unable to internally regulate the body temperature, instead relying on external means such as the Sun, as in cold-blooded animals such as reptiles; cf endothermic.

**egg sac** A silk bag that some spiders spin around their eggs. Some egg sacs are portable, so the eggs can be carried from place to place. Others are more like a blanket, and are attached to leaves or suspended from twigs.

**egg tooth** A special scale on the tip of the upper lip of a hatchling lizard or snake. It is used to break a hole in the egg so that the newborn animal can escape. The egg tooth falls off within a few days of hatching.

**electroreceptors** Specialized organs found in some fishes (such as sharks) and mammals (such as platypuses) that detect electrical activity from the bodies of other animals. They also help the animal to navigate by detecting distortions in the electrical field of its surroundings—for example, those caused by a reef.

**elytra** The thickened front wings of beetles that cover and protect the back wings.

**embryo** An unborn animal in the earliest stages of development. An embryo may grow inside its mother's body, or in an egg outside her body.

**endothermic** Able to regulate the body temperature internally, as in warm-blooded animals; cf exothermic.

**estivate** To spend a period of time in a state of inactivity to avoid unfavorable conditions. During times of drought, many frogs greatly reduce their overall metabolic rate and estivate underground until rain falls.

**evolution** Gradual change in plants and animals, over many generations, in response to their environment.

**exoskeleton** A hard external skeleton or body case. All arthropods are protected by an exoskeleton.

**exotic** A foreign or non-native species of animal or plant, often introduced into a habitat by humans.

**feral** A wild animal or plant, or a species that was once domesticated but has returned to its wild state.

**fledgling** A young bird that has recently grown its first true feathers and has just left its nest.

**flippers** The broad front (and often, back) legs of some aquatic animals. Flippers are composed mainly of the bones of the fingers and hand, and act like paddles to row the animal through the water.

**food chain** A system in which one organism forms food for another, which in turn is eaten by another, and so on. The first organism is usually an alga or other single-celled life form in an aquatic food chain, and a plant in a terrestrial food chain.

**fossil** A remnant, impression, or trace of a plant or animal from a past geological age, usually found in rock.

**fossorial** Adapted to digging or burrowing underground.

**frill** In a lizard, a collar around the neck. Like a crest or dewlap, a frill can be raised to signal to other lizards or to surprise a predator.

**fry** Young or small fishes.

**gastroliths** Stones swallowed by such animals as crocodilians, that stay in the stomach to help crush food.

**gestation period** The period of time during which a female animal is pregnant with her young.

**gills** Organs that collect oxygen from water and are used for breathing. Gills are found in many aquatic animals, including fishes, some insects, and the larvae of amphibians.

**gizzard** In birds, the equivalent of the stomach in mammals. Grit and stones inside the gizzard help to grind up food. Food passes from the gizzard to the intestines.

**global warming** The increase in the temperature of Earth and its lower atmosphere due to human activity such as deforestation, land degradation, intensive farming, and the burning of fossil fuels. This causes the absorption of heat by water vapor and "greenhouse" gases, including carbon dioxide and methane. The trapped heat, which would otherwise be radiated out to space, may cause the polar icecaps to melt and ocean levels to rise. Global warming is also known as "the greenhouse effect."

**Gondwana** Ancient southern supercontinent, comprising the present-day continents of Australia, India, Africa, South America, and Antarctica; see also Laurasia, Pangea.

**gravid** Full of eggs; pregnant.

**grazer** An animal that eats grasses and plants that grow on the ground.

**greenhouse effect** See global warming.

**groom** Of an animal, to clean, repair, and arrange the fur.

**grub** An insect larva, usually that of a beetle.

**gullet** Found in birds, the gullet is the equivalent of the esophagus in mammals. This tube passes food from the bill to the gizzard.

**habitat** The area in which an animal naturally lives. Many different kinds of animals live in the same environment (for example, a rain forest), but each kind lives in a different habitat within that environment. For example, some animals in a rain forest live in the trees, while others live on the ground.

**harem** A group of female animals that mate and live with one male.

**hatchling** A young animal, such as a bird or reptile, that has recently hatched from its egg.

**heat-sensitive pit** Sense organs in some snakes that detect tiny changes in temperature.

**herbivore** An animal that eats only plant material, such as leaves, bark, roots, and seeds; cf carnivore, omnivore.

**hermaphrodite** A plant or animal either possessing both male and female sex organs at the same time, and thus able to fertilize itself (known as simultaneous hermaphroditism), or one that starts life as one sex and later changes to the other (sequential hermaphroditism); see also protandrous, protogynous.

**hibernate** To remain completely inactive during the cold winter months. Some animals eat as much as they can before the winter, then curl up in a sheltered spot and fall into a very deep sleep. They live off stored fat, and slow their breathing and heartbeat to help conserve energy until spring. Insects may hibernate as eggs, larvae, pupae, or adults.

**hoof** The toe of a horse, antelope, deer, or related animal that is covered in thick, hard skin with sharp edges.

**horns** In mammals such as ruminants, pointed, hollow, bony outgrowths on the head. Unlike antlers, horns are not shed.

**hybrid** The offspring of parents of two different species.

**incisors** The front teeth of an animal, located between the canines, used for cutting food.

**incomplete metamorphosis** A system of development in which a young insect gradually changes shape from an egg, to a nymph, to an adult.

**incubate** To keep eggs in an environment, outside the female's body, in which they can develop and hatch. Most birds incubate their eggs by warming them with their body heat. The eggs of other birds and reptiles may incubate in soil, leaf litter, or a similar covering, with no further input from the parents.

**insectivore** An animal that eats only or mainly insects or invertebrates. Some insectivores also eat small vertebrates, such as frogs, lizards, and mice. In mammals, a member of the order Insectivora.

**introduced** An animal or plant species imported from another place by humans and deliberately or accidentally released into a habitat.

**invertebrate** An animal with no backbone. Many invertebrates are soft-bodied animals, such as worms, leeches, or octopuses, but most have an exoskeleton, or hard external skeleton, such as insects.

**ivory** The tusks or enlarged teeth of elephants and walrus, or objects manufactured from them.

**Jacobson's organ** Two small sensory pits on the top part of the mouth of snakes, lizards, and mammals. They use this organ to analyze small molecules picked up from the air or ground with their tongue.

**keratin** A protein found in horns, hair, scales, feathers, and fingernails.

**krill** Small, shrimplike crustaceans that live in huge numbers in Arctic and Antarctic waters.

**lateral line** A sensory canal system along the sides of a fish. It detects moving objects by registering disturbances (or pressure changes) in the water.

**larva** (pl. larvae) A young animal that looks completely different from its parents. An insect larva, sometimes called a grub, maggot, or caterpillar, changes into an adult by either complete or incomplete metamorphosis. In amphibians, the larval stage is the stage before metamorphosis that breathes with gills rather than lungs (for example, tadpoles).

**Laurasia** Ancient northern supercontinent, comprising the present-day Asia, North America, and Europe; see also Gondwana, Pangea.

**live-bearing** Giving birth to young that are fully formed.

**luminous** Reflecting or radiating light. Some deepsea fishes can produce their own light source by using luminous bacteria.

**maggot** The larva of a fly.

**mammal** A warm-blooded vertebrate that suckles its young with milk and has a single bone in its lower jaw. Although most mammals have hair and give birth to live young, some, such as whales and dolphins, have very little or no hair; others, the monotremes, lay eggs.

**mandibles** Biting jaws of an insect.

**marsupial** A mammal that gives birth to young that are not fully developed. These young are usually protected in a pouch (where they feed on milk) before they can move around independently.

**mesopelagic** Of or associated with the deep sea, from about 600 to 3,000 feet (200 to 1,000 m).

**metamorphosis** A way of development in which an animal's body changes shape. Many invertebrates, including insects, as well as some vertebrates, such as amphibians, metamorphose as they mature.

**migration** A usually seasonal journey from one habitat to another. Many animals migrate vast distances to another location to find food, or to mate and lay eggs or give birth. Some deep-sea fishes migrate vertically at night to feed.

**molars** A mammal's side cheek teeth, used for crushing and grinding.

**mollusk** An animal, such as a snail or squid, with no backbone and a soft body that is often partly or fully covered by a shell.

**molt** To shed an outer layer of the body, such as hair, skin, scales, or the exoskeleton.

**monotreme** A primitive mammal with many features in common with reptiles. Monotremes lay eggs and have a cloaca. They are the only mammals that lack teats, although they feed their young milk released through ducts on their belly.

**morph** A color or other physical variation within, or a local population of, a species.

**musth** In elephants, a time of high testosterone levels when the musth gland between the eye and ear secretes fluid; associated with mating and characterized by increased aggression and searching for females.

**mutualism** An alliance between two species that is beneficial to both, as in ox-peckers and grazing herbivores.

**neoteny** The retention of some immature or larval characteristics into adulthood. Some salamander species are usually or often neotenic.

**niche** The ecological role played by a species within an animal community.

**nocturnal** Active at night. Nocturnal animals have special adaptations, such as large, sensitive eyes or ears, to help them find their way in the dark. All nocturnal animals rest during the day.

**nomadic** Lacking a fixed territory, instead wandering from place to place in search of food and water.

**nymph** The young stage of an insect that develops by incomplete metamorphosis. Nymphs are often similar to adults, but do not have fully developed wings.

**ocellus** A kind of simple eye with a single lens. Insects usually have three ocelli on the top of their head.

**omnivore** An animal that eats both plant and animal food. Omnivores have teeth and a digestive system designed to process almost any kind of food.

**opposable** Describing a thumb that can reach around and touch all of the other fingers on the same hand, or a toe that can similarly touch all of the other toes on the same foot.

**order** A major group used in taxonomic classification. An order forms part of a class, and is further divided into one or more families.

**osteoderm** In reptiles, a lump of bone in the skin that provides protection against predators. Most crocodilians and some lizards are protected by osteoderms, as well as by thick, strong skin.

**oviparous** Reproducing by laying eggs. Little or no development occurs within the mother's body; instead, the embryos develop inside the egg; cf ovoviviparous, viviparous.

**ovipositor** A tubelike organ through which female insects lay their eggs. The stinger of bees and wasps is an modified ovipositor.

**ovoviviparous** Reproducing by giving birth to live young that have developed from eggs within the mother's body. The eggs may hatch as they are laid or soon after; cf oviparous, viviparous.

**pair bond** A partnership maintained between a male and a female animal, particularly birds, through one or several breeding attempts. Some species maintain a pair bond for life.

**paleontology** The scientific study of life in past geological periods.

**Pangea** Ancient supercontinent in which all the present-day continents were once joined; see also Gondwana, Laurasia.

**parallel evolution** The situation in which related groups living in isolation develop similar structures to cope with similar evolutionary pressures.

**parasitism** The situation in which an animal or plant lives and/or feeds on another living animal or plant, sometimes with harmful effects.

**passerine** Any species of bird belonging to the order Passeriformes. A passerine is often described as a songbird or a perching bird.

**pectoral fins** In fishes and aquatic mammals, the paired fins attached to each side of the animal and used for lift and control of movement. In fishes, they are usually located just behind the gills.

**pedicel** The narrow "waist" that connects an insect's head to its thorax, or a spider's cephalothorax to its abdomen.

**pedipalp** One of a pair of small, leglike organs on the head of insects and the cephalothorax of spiders and scorpions, used for feeling or for handling food. In spiders, they are also used for mating.

**pelagic** Swimming freely in the open ocean; not associated with the bottom; cf benthic.

**pelvic fins** Paired fins, located on the lower part of a fish's body.

**photophores** Luminous organs on some deep-sea fishes.

**pheromone** A chemical released by an animal that sends a signal and affects the behavior of others of the same species. Many animals use pheromones to attract mates, or to signal danger.

**phytoplankton** Tiny, single-celled algae that float on or near the surface of the sea.

**placental mammal** A mammal that does not lay eggs (as monotremes do), or give birth to underdeveloped young (as marsupials do). Instead, it nourishes its developing young inside its body with a blood-rich organ called a placenta.

**plankton** The plant (phytoplankton) or animal (zooplankton) organisms that float or drift in the open sea. Plankton forms an important link in the food chain.

**pollen** A dustlike substance produced by male flowers, or by the male organs in a flower, and used in reproduction.

**pollination** The process by which the pollen produced by the male organs of a flower come into contact with the female parts of the flower, thus fertilizing the flower and enabling seeds to form.

**pore** A minute opening, as in the skin of an animal or the leaf surface of a plant.

**precocial** Active and self-reliant at birth. Describes newly hatched chicks of some birds, such as ducks and chickens; cf altricial.

**predator** An animal that lives mainly by killing and eating other animals.

**preen** Of a bird, to clean, repair, and arrange plumage.

**prehensile** Grasping or gripping. Some tree-dwelling mammals and reptiles have prehensile feet or a tail that can be used as an extra limb to help them stay safely in a tree. Elephants have a prehensile "finger" on the end of their trunk so they can pick up small pieces of food. Browsers, such as giraffes, have prehensile lips to help them grip leaves. The prehensile tongue of parrots enables them to extract kernels from shells.

**proboscis** In insects, a long, tubular mouthpart used for feeding. In some mammals, a proboscis is an elongated nose, snout, or trunk. That of an elephant has many functions, such as smelling, touching, and lifting.

**protandrous** Of sequential hermaphrodites (as in some fishes), starting life as a male and later becoming female.

**protogynous** Of sequential hermaphrodites (as in some fishes), starting life as a female and later becoming male.

**pupa** (pl. pupae) The stage during which an insect transforms from a larva to an adult.

**queen** A female insect that begins a social insect colony. The queen is normally the only member of the colony that lays eggs.

**quill** Long, sharp hair of an echidna, porcupine, anteater, and a few other mammals; used for defense.

**rain forest** A tropical forest that receives at least 100 inches (250 cm) of rain each year. Rain forests are home to a vast number of plant and animal species.

**raptor** A diurnal bird of prey, such as a hawk or falcon. The term is not used to describe owls.

**regurgitate** To bring food back up from the stomach to the mouth. Many hoofed mammals use this process to break down their food into a more liquid form. This is called chewing the cud. Birds also regurgitate partially digested food to feed to their chicks.

**roost** A place or site used by some animals, such as birds and bats, for sleeping. Also, the act of traveling to or gathering at such a place.

**refection** A practise of some rodents, in which they eat their own fecal matter to gain maximum nutrition from the food, before passing feces as dry pellets.

**retractile claws** The claws of cats and similar animals that are usually protected in sheaths. Such claws spring out when the animal needs them to capture prey or to fight.

**rostrum** A tubular, beak-like feeding organ on the head of some insects.

**rudimentary** Describes a simple, undeveloped, or underdeveloped part of an animal, such as an organ or wing. The rudimentary parts of some modern-day animals are the traces of the functional parts of an early ancestor, but now serve no purpose.

**ruminants** Hoofed animals—cattle, buffalo, bison, antelopes, gazelles, sheep, goats, and other members of the family Bovidae—with a four-chambered stomach. One of these chambers is the rumen, in which food is fermented by microorganisms before being regurgitated and chewed a second time. This efficient digestive system allows bovids to make the most of low-nutrient foods such as grasses, and to colonize a wide array of habitats.

**savanna** Open grassland with scattered trees. Most savannas are found in subtropical areas that have a distinct summer wet season.

**scales** In reptiles, distinct thickened areas of skin that vary in size, from very small to large; in fishes, small plates that form part of the external body covering.

**scavenger** An animal that eats carrion—often the remains of animals killed by predators.

**scutes** In a turtle or tortoise, the horny plates that cover the bony shell.

**sedentary** Having a lifestyle that involves little movement; also used to describe animals that do not migrate.

**semi-aquatic** Living some of the time in water, and some of the time on land.

**silk** A strong but elastic substance made by many insects and spiders. Silk is liquid until it leaves the animal's body.

**social** Living in groups. Social animals can live in breeding pairs, sometimes together with their young, or in a colony or herd of up to thousands of animals.

**spawn** To release eggs and sperm together directly into the water.

**species** A group of animals with very similar features that are able to breed together and produce fertile young.

**spermatophore** A container or package of sperm that is passed from male to female during mating.

**spicule** A minute, needle-like, siliceous or calcareous body, found in invertebrates.

**spinnerets** The fingerlike appendages of spiders that are connected to silk glands, found near the tip of the abdomen.

**spiracle** A small opening that leads into the trachea, or breathing tube, of an insect or spider. In cartilaginous fishes, spiracles are located behind the eyes. They take in water for breathing when the fish is at rest on the bottom, or when the mouth is being used for feeding.

**squalene** A substance found in the liver oil of deep-sea sharks. It is refined and used as a high-grade machine oil in high-technology industries, as a human health and dietary supplement, and in cosmetics.

**stinger** A hollow structure on the tail of insects and scorpions that pierces flesh and injects venom.

**streamlined** Having a smooth body shape to reduce drag, as in seals.

**stereoscopic vision** Vision in which both eyes face forward, giving an animal two overlapping fields of view and thus allowing it to judge depth.

**stridulate** To make a sound by scraping objects together. Many insects communicate in this way, some by scraping their legs against their body.

**stylet** A sharp mouthpart used for piercing plants or animals.

**subantarctic** Of the oceans and islands just north of Antarctica.

**swim bladder** A gas-filled, baglike organ in the abdomen of bony fishes. It enables the fishes to remain at a particular depth in the water.

**symbiosis** An alliance between two species that is usually (but not always) beneficial to both. Animals form symbiotic relationships with plants, microorganisms, and other animals; cf mutualism, parasitism.

**sympatric** Of two or more species, occurring in the same area.

**syndactylic** Having fused toes on the hindfoot, as in bandicoots, kangaroos, and wombats.

**tadpole** The larva of a frog or toad. Tadpoles are aquatic and take in oxygen from the water through gills.

**taxonomy** The system of classifying living things into various groups and subgroups according to similarities in features and adaptations.

**teleosts** Bony fishes.

**terrestrial** Living all or most of the time on land; cf amphibious, aquatic.

**temperate** Describes an environment or region that has a warm (but not very hot) summer and a cool (but not very cold) winter. Most of the world's temperate regions are located between the tropics and the polar regions.

**tentacles** On marine invertebrates, long, thin structures used to feel and grasp, or to inject venom. On caecilians, sensory organs located on the sides of the head, possibly used for tasting and smelling.

**territory** An area of land inhabited by an animal and defended against intruders. The area often contains all the living resources required by the animal, such as food and a nesting or roosting site.

**thermal** A column of rising air, used by birds to gain height, and on which some birds soar to save energy.

**thorax** The middle part of an animal's body. In insects, the thorax is divided from the head with a narrow "waist," or pedicel. In spiders, the thorax and head make up a single unit.

**torpid** In a sleep-like state in which bodily processes are greatly slowed. Torpor helps animals to survive difficult conditions such as cold or lack of food. Estivation and hibernation are types of torpor.

**trachea** A breathing tube in an animal's body. In vertebrates, there is one trachea (or windpipe), through which air passes to the lungs. Insects and some spiders have many small tracheae that spread throughout the body.

**tropical** Describes an environment or region near the Equator that is warm to hot all year round.

**tropical forests** Forests growing in tropical regions, such as central Africa, northern South America, and southeast Asia, that experience little difference in temperature throughout the year. See rain forest.

**tundra** A cold, barren area where much of the soil is frozen and the vegetation consists mainly of mosses, lichens, and other small plants adapted to withstand intense cold. Tundra is found near the Arctic Circle and on mountain tops.

**tusks** The very long teeth of such mammals as elephants, pigs, hippos, musk deer, walruses, and narwhals; used in fights and for self-defense.

**ungulate** A large, plant-eating mammal with hoofs. Ungulates include elephants, rhinoceroses, horses, deer, antelope, and wild cattle.

**venom** Poison injected by animals into a predator or prey through fangs, stingers, spines, or similar structures.

**venomous** Describes an animal that is able to inject venom into another. Venomous animals usually attack by biting or stinging.

**vertebrate** An animal with a backbone. All vertebrates have an internal skeleton of cartilage or bone. Fishes, reptiles, birds, amphibians, and mammals are vertebrates.

**vertebral column** The series of vertebrae running from head to tail along the back of vertebrates, and which enclsoes the spinal cord.

**vestigial** Relating to an organ that is non-functional or atrophied.

**vibrissae** Specialized hairs, or whiskers, that are extremely sensitive to touch.

**viviparous** Reproducing by means of young that develop inside the mother's body and are born live; sometimes called placental viviparity. Most mammals and some fishes (such as sharks) are viviparous.

**warm-blooded** See endothermic.

**worker** A social insect that collects food and tends a colony's young, but which usually cannot reproduce.

**zooplankton** The tiny animals that, together with phytoplankton, form the plankton that drifts on or near the sea's surface. Zooplankton are eaten by some whales, fishes, and seabirds.

**zygodactylous** Of birds, having two of the four toes pointing forward, and the other two pointing backward.

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t=top; l=left; r=right; tl=top left; tcl=top center left; tc=top center; tcr=top center right; tr=top right; cl=center left; c=center; cr=center right; b=bottom; bl=bottom left; bcl=bottom center left; bc=bottom center; bcr=bottom center right; br=bottom right

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Tonia Johansen/Johansen Indexing Services.

The publishers wish to thank Brendan Cotter, Helen Flint, Frankfurt Zoological Society, Paul McNally, Kathryn Morgan, and Tanzania National Parks for their assistance in the preparation of this volume.

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# THE ENCYCLOPEDIA OF ANIMALS

## A Complete Visual Guide

An international team of experts in the zoological sciences has directed the preparation of this book to ensure that it provides the latest scientific information in an accessible style that will bring the animal kingdom to life as never before.

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**Section and chapter**
This indicates the group of animals under discussion.

**Group global distribution**
A map shows the worldwide distribution of the group being profiled, followed by text that discusses the distribution of particular groups in more detail.

**Label**
The labels highlight distinguishing aspects or characteristics of the species, such as color variations, behavior, habitat, size, and anatomical features.

**Fact file**
This profiles one or more of the illustrated species or groups, with information about its size, range, habitat, appearance, reproduction, migratory habits, behavior, calls, or regional variations.

**Classification box**
This indicates the taxonomic groups to which the animals belong in the animal kingdom.

**Habitat icons**
The icons indicate the various habitats in which the profiled animal(s) can be found, for example coral reefs or rain forest.

**Distribution map**
This shows the species' or group's range (and former range, where appropriate). If distributed throughout the world, a world map is shown; if regional distribution, a map of that area only is given.

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Where appropriate, diagrams are included to illustrate points about anatomy or adaptation.

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**Feature box**
This support text describes in detail a facet of the species' behavior or biology, and is accompanied by relevant photographs, illustrations, or diagrams.

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This provides information about the status of a particular species or group of animals, according to the IUCN Red List of Threatened Species. These boxes may also outline factors that threaten the animal's survival.

**Conservation symbols**
A red cross above the species' name indicates that it is extinct or extinct in the wild; a red flash indicates that it is critically endangered or endangered according to the IUCN Red List.

**Name labels**
Labels indicate the common and scientific names, as well as the species' family, order, or class, where appropriate.

ISBN-13: 978-0-520-24406-1
ISBN-10: 0-520-24406-0
9 780520 244061

University of California Press
Berkeley 94704
www.ucpress.edu

Printed in Singapore